Engin.
rary

AUG 13 1929

METALS & ALLOYS

Devoted to the Advancement of Scientific Metallurgy

Two Decades of Precipitation Hardening Alloys

DR. ZAY JEFFRIES

Strategic Raw Materials

MAJ. ROGER TAYLOR

Demands of Chemical Industry on Metallurgy

DR. B. D. SAKLATWALLA

X-Ray Metallography in 1929

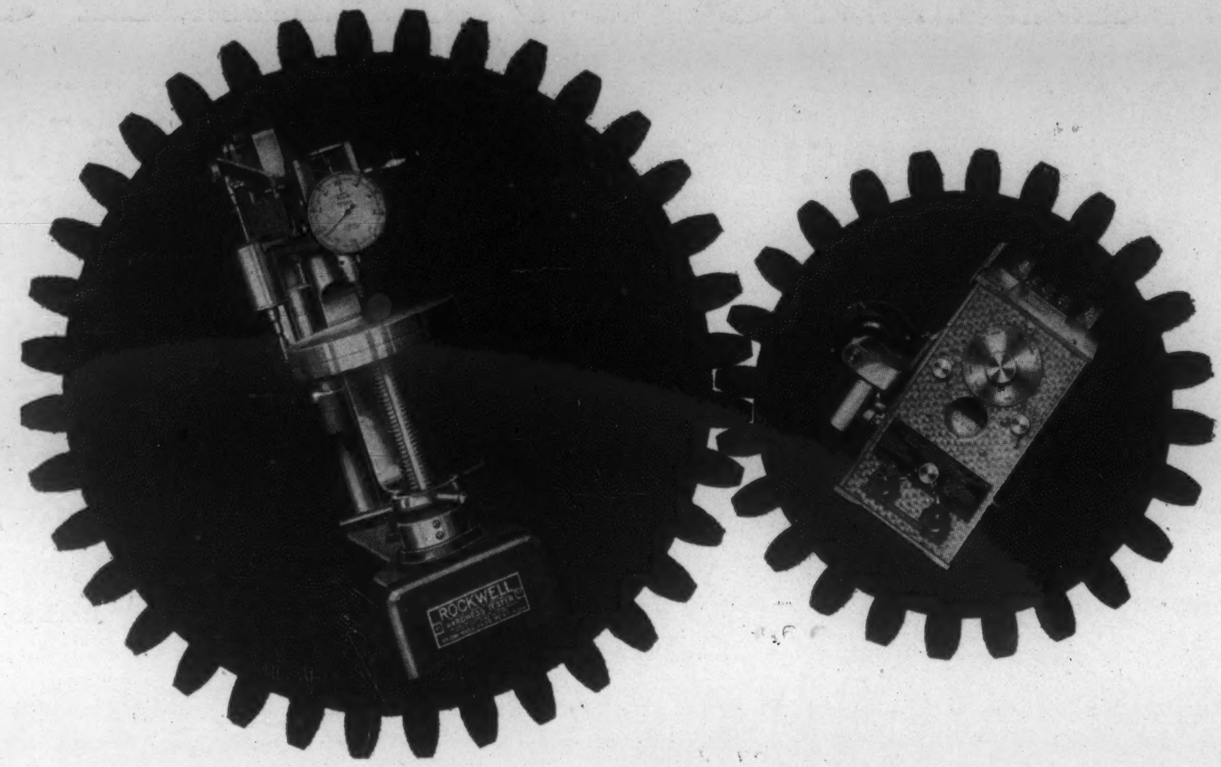
PROF. GEORGE L. CLARK

NUMBER 1
40 Cents a Copy

JULY 1929

VOLUME 1
$3.00 a Year

Naturally Geared Together



The

ROCKWELL HARDNESS TESTER

and

WILSON-MAEULEN PYROMETER CONTROLLERS

The Rockwell Tester has been a driving force for better annealing and heat-treating. Automatic Control of Furnace Temperature has moved forward as a consequence.

Those who use Wilson-Maeulen Controllers have been able to so improve furnace operation that little defective work has come from furnace operation and because more of the product is good, the net result of Rockwell Hardness Testing has been to increase the quantity of salable product as well as to increase its quality.

A Wilson-Maeulen Representative awaits your call for a conference.

WILSON-MAEULEN CO
INCORPORATED
733 East 143rd Street New York, N. Y.

METALS & ALLOYS

Devoted to the Advancement of Scientific Metallurgy

East Eng. Lib;
Chem-Eng
Faxon
8-13-29
Sub.

Published Monthly by
THE CHEMICAL CATALOG COMPANY, INC.

Publication Office: 20th and Northampton Sts., Easton, Pa.
Editorial and Advertising Office: 419 Fourth Ave., New York

BRANCH OFFICES:
953 Leader Building
Cleveland
1050 Straus Building
Chicago
703 Market Street
San Francisco

Francis M. Turner, Jr., Pres. *L. F. Nellis, Vice-Pres.* *H. Burton Lowe, Vice-Pres.* *R. W. Reinhold, Secy.-Treas.*

VOL. 1 **JULY, 1929** **NO. 1**

CONTENTS

Page

Editorials 1

Contributed Articles

Two Decades of Precipitation Hardening Alloys .... ZAY JEFFRIES 3
Strategic Raw Materials .... ROGER TAYLOR 5
Demands of Chemical Industry on Metallurgy .... B. D. SAKLATWALLA 8
X-Ray Metallography in 1929 .... GEORGE L. CLARK 14
A New Method of Testing the Depth of Case on Carburized Steel .... F. A. FIRESTONE AND E. J. ABBOTT 18

Departments

Correlated Abstracts 19
- So-Called "Accelerated" Endurance Testing of Metals, with a Review of Ikeda's Method. H. W. GILLETT
- Have Heat-Treated Aluminum Alloys a True Endurance Limit? H. W. GILLETT

Abstracts of Current Metallurgical Literature 23

Translations 29
- A Contribution to the Knowledge on the System Nickel-Iron. G. F. SIZOO AND C. ZWICKER, Eindhoven
- X-Ray Examination of Aluminum at High Temperatures. A. J. ALICHANOW, Leningrad

Book Reviews 31

Patent Department 33

News 38
- "High Spots" of the 32nd Annual Meeting of the American Society for Testing Materials
- National Metals Congress
- Electrochemists to Discuss Aviation Materials
- Battelle Memorial Institute
- Personals

Reviews of Manufacturers' Literature 44

Miscellaneous

International Standardization To Be Considered 13
Analysis of Steel for Manganous Oxide 17
Slag Suitable for Making Ferromanganese Made in Electric-Furnace Tests 18
Slag Viscosity and Its Relation to Open-Hearth Operation 43
Statistics of Refined Primary Lead in the United States in 1928 43

H. W. Gillett, Editorial Director

Francis M. Turner, Jr., Managing Editor
Richard Rimbach, Associate Editor

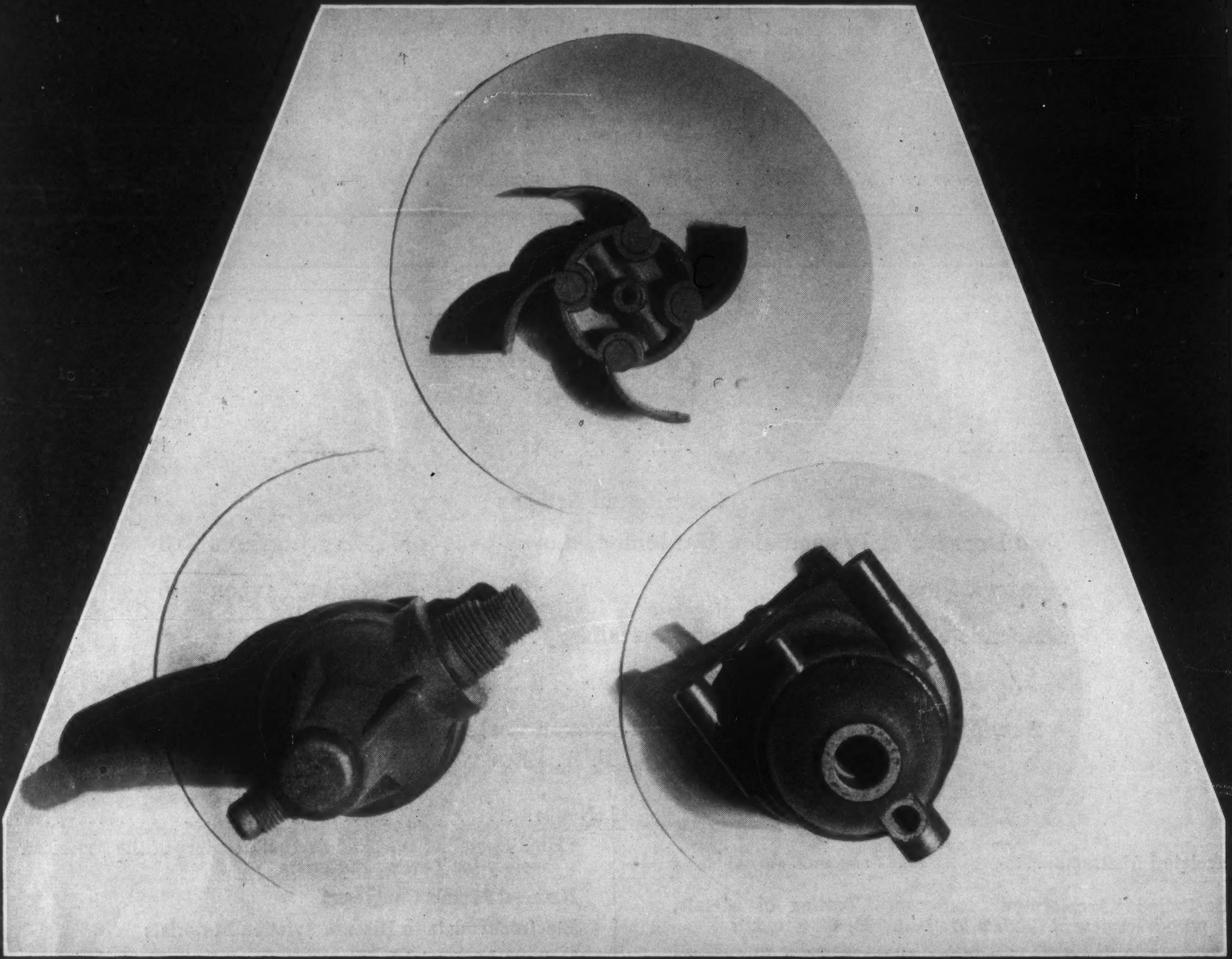
Annual Subscription: U. S., Possessions and Cuba, $3.00; Canada, $3.50; Other Countries, $4.00; Single copies, 40c.

Copyright, 1929, by The Chemical Catalog Company, Inc. All rights reserved.

Application made for entry at the Post-Office at Easton, Pennsylvania, as second-class matter.

HORSE HEAD ZINC

FOR THE DIE CASTING INDUSTRY



CASTINGS, COMPLETE WHEN CAST

Speed of production demands castings full-grown at birth. ℭ Look at these die-castings. You see threads . . . born full-grown when the mold was opened. You see unmachined parts fitting closely into other unmachined parts . . . born with close clearances. You see perfect core holes, untouched by cutting tools . . . another birthright of die-casting. ℭ You see three zinc-base die-castings born to man's estate. *Not one ever felt the growing pains of machining.* ℭ Horse Head Zinc is the base of each. These castings are as serviceable as the die-casting process is efficient. The *uniform quality* of Horse Head Zinc assures long-life castings to the user.

New Jersey zinc

THE NEW JERSEY ZINC SALES CO.
160 FRONT STREET, NEW YORK CITY

ZINC METALS AND ALLOYS - ROLLED ZINC - ZINC PIGMENTS - SULPHURIC ACID - SPIEGELEISEN

PUBLISHERS PAGE

Note—On this page the publishers will talk right straight to you each month. We will tell you how things are progressing with METALS & ALLOYS. *We will undoubtedly ask your advice on many points. We are publishing this paper not primarily to please ourselves but rather to serve you. And our office door is always open. You are invited to call.*

We Make a Bow!

FIRST, we wish most heartily to thank all those who have so promptly expressed their approval of the idea back of METALS & ALLOYS by sending in their subscriptions to begin with this, our first issue. The response to our announcement has not only been most gratifying but, what is more, it shows beyond the possibility of a doubt that an American journal devoted to scientific metallurgy is very much wanted. The publishers sincerely hope that the paper will meet the expectations and possibly some of the hopes of those who have so warmly supported the idea.

METALS & ALLOYS will be devoted to the advancement of scientific metallurgy. Under the able editorial direction of Dr. Gillett and those who will assist him it will be our constant aim to make each issue of the paper a genuine and helpful contribution to the great and important fields which it strives to serve. It is our plan not only to make METALS & ALLOYS indispensable to those conducting metallurgical research but also of great practical value to that large and important group of manufacturers who must of necessity keep abreast of the times so that the materials entering into the manufacture of their own products may conform in all respects to the most enlightened and up-to-date practice. In other words users of metals and their alloys in countless different forms and for a great diversity of uses will find METALS & ALLOYS well worth reading as it appears each month.

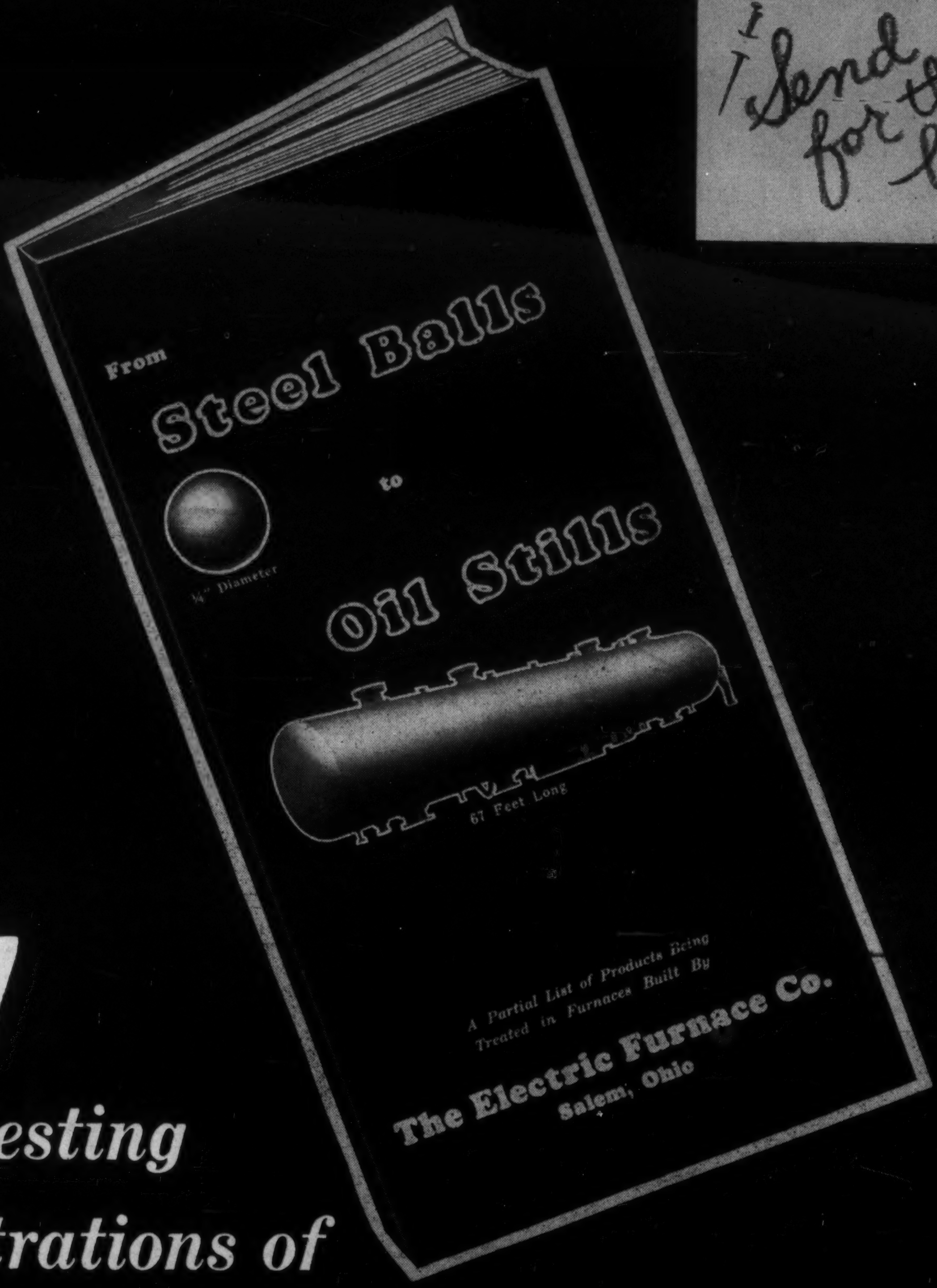
While the editors have prepared a schedule of leading articles for the greater part of the rest of the year it is hoped that no one will be bashful about suggesting topics which might to advantage be included in our program. Contributions coming within the scope of our activities will at all times be carefully and promptly considered. Suggestions will always be welcome. Criticism is invited and we mean it. It will of course take us a few months to make it clear to you just exactly what kind of a paper METALS & ALLOYS is going to be. While we are by no means ashamed of this issue we are confident that it is but a pale forerunner of what METALS & ALLOYS will be when it really gets into its stride.

We wish especially to direct your attention to the various departments which are but indicated in outline in this number. Arrangements are now in progress to provide for a splendid foreign department with representatives in all European centers, and also to perfect our system for handling abstracts. Possibly other departments will occur to you which might to advantage be added to subsequent issues. We are here to listen. It is our theory that such a journal as METALS & ALLOYS should be edited *with* its readers rather than entirely *for* them. We could undoubtedly formulate and carry out a fairly interesting editorial program without consulting anybody but we are absolutely sure that with the active cooperation of our readers we shall be able to make METALS & ALLOYS one of the best technical journals published today.

As the press starts to print this page we have 2246 names on our subscription list. More than 10,000 copies of this issue will be printed. Since it is impossible for a publisher to print and store a large stock of issues of a periodical, may we suggest that you urge any of your acquaintances who should be interested in this paper to subscribe at once. Otherwise the stock of early issues may not be available later on, rendering it impossible for the subscriber to maintain a complete file from the beginning.

Our hat is off to the Charter Subscribers! The encouragement to our undertaking furnished by their subscriptions and the hundreds of letters accompanying them has only served to strengthen our resolution to make METALS & ALLOYS a better journal than they expect.

Send for this book


From
Steel Balls
3/4" Diameter
to
Oil Stills
67 Feet Long
A Partial List of Products Being Treated in Furnaces Built By
The Electric Furnace Co.
Salem, Ohio

67

interesting illustrations of

Electric Furnaces

are shown in this book. It illustrates some of the world's largest and most noteworthy installations and lists some of the numerous products treated in electric furnaces.

Handling most everything from small steel balls for ball bearings to large oil stills these furnaces are speeding production and making some remarkable records for economy of operation, uniformity of results and quality of products.

Send for a copy—no doubt your product is listed or can be handled to advantage in an electric furnace.

The Electric Furnace Company
Salem, Ohio
Heat Treating Equipment Specially Designed For Any Requirement

"Volume 1, No. 1"

To justify the launching of a new journal, there must be a need to be filled. That a need exists in the field of scientific metallurgy which justifies and demands the launching of METALS & ALLOYS has long been evident.

Modern civilization is based on the finding of new facts by scientific research and on the speedy application of those facts to practical use. Metals and alloys are key materials in everything that serves mankind in the household, in business, in industry, in transportation and actually in all lines of endeavor. It is obvious that the performance of aircraft, automobiles, railroads, ships, all electrical apparatus, most chemical equipment and, in fact, all machinery, is directly dependent on the quality and suitability of the metallic materials used.

The production of non-metallic commodities is less obviously but no less truly affected by metals, operating behind the scenes. Economical production of food, textiles, coal, lumber, glass, cement, paper, leather, rubber and any other non-metallic material you may care to name can be shown to depend directly on the proper functioning of some metallic tool, machine, container, or what not, whose properties must be such as to fit the exact problem in hand.

From the time the new-born infant is given his first bath in an enameled metal tub till he is laid to rest in a metallic grave-vault, he is continually served by metallic elements and alloys.

Four-fifths of the chemical elements are metals. For the better utilization of these metals and their multitudinous alloys the modern scientific metallurgist applies the pyrometer, the microscope, the spectroscope, the X-ray spectrograph and radiograph, chemical analysis and mechanical testing, magnetic, electrical, thermoelectric and many other tests. His tools are increasing in number and in sensitivity and precision. Principles and theories for the interpretation of his observations such as the phase rule and the slip interference theory of hardening, based on physics, chemistry and physical chemistry, have been developed till there is truly in existence (as indicated by the title of Dr. Jeffries' well-known book) a "Science of Metals." With this wealth of material and methods at hand and with the multitude of demands upon the engineer for metals of better quality and uniformity, better strength, lower cost, and for those suited to resist more and more severe conditions of corrosion, wear, high temperature and repeated stress, the metallurgist has a complex task and a large responsibility.

Fortunately, no metallurgist has to work single-handed. The large metal-using and metal-producing industries in all countries are increasing their metallurgical research staffs and equipment at an unprecedented rate. These scientists know that their unaided efforts will not carry them far and that it is wise to swap the little they know individually for the much that others know collectively. Hence secrecy is increasingly rare and cooperation the rule. Scientific societies dealing wholly or chiefly with metals and alloys are flourishing, and their transactions, in English, German, French, Swedish, Russian, Japanese, Italian, etc., contain thousands of papers every year. Most of these papers would materially advance the knowledge of anyone interested in metals provided he had time to read them and assimilate them.

Each metallurgist thus has thousands of cooperators whose knowledge is of potential value to him. His problem is to knit this new knowledge into the fabric of his present knowledge, without spending all his time in the knitting. Various index services offer reasonably complete lists of titles of current publications and some abstracts are available which will allow him to select some of the useful ones for perusal and study.

There is need for something more than a mere inventory of scattered facts. Sometimes a fact is self-sufficient and its application obvious. More often its main value lies in the light it throws on other facts. Certainly it is easier to remember and to utilize new information when it is considered in relation to the broader aspects of the problem. Books and monographs on particular phases of metallurgy do much more than recount facts; they put them in assimilable form, and show the gaps in existing information that should be filled by research.

When the Engineering Foundation recently asked some fifty iron and steel metallurgists what was the greatest service that could be done to the iron and steel industry, they were unanimous in stating that even more important than the finding of new facts was the compilation and correlation of those facts already on record but largely unappreciated and unused.

The fruition of this Engineering Foundation project on iron and steel is still in the future, and non-ferrous alloys are not included in the scheme. With that scheme in full blast there will still be need for a running compilation and correlation to render available the data as they accumulate between revisions of the monographs. Correlated abstracting of both ferrous and non-ferrous metallurgical literature as distinct from mere indexing or cursory abstracting of single articles is uncared for in this country. It is of interest to note that London *Engineering* has for four years published a small monthly supplement, "The Metallurgist," which is primarily concerned with correlated abstracting. The engineer, i. e., the user of metals, is the one who most needs unbiased presentation of the new facts of metallurgy, for he is the one who must apply them to practice. While the bulk of the new facts will continue to come from the producer of metals, the user will not rest content with what the producer may find out, but will search out the facts needed for the solution of his own problems. Witness the contributions to metallurgical knowledge made by the Western Electric Company and its associated industries, by the Westinghouse and the General Electric Companies, to refer to users in the electrical field only.

There seems to be a real need for a journal of scientific metallurgy conducted primarily in the interest of, and from the point of view of, the user of metals. METALS & ALLOYS is an attempt to fill the need. Its task is to collect, and to present impartially, information on the scientific advances in both ferrous and non-ferrous metallurgy in such form that they may be more readily assimilated into engineering practice, to bridge the gap between the sometimes abstruse findings of the research laboratory and the everyday use of those findings to make better and cheaper goods for human consumption.

Scientific societies, government laboratories, engineering experiment stations of universities and other organizations in general publish only completed investigations, and it is proper that only well-ripened facts be so published. Yet the livest problems are often those with the scantiest literature. Society symposia are of service in showing the "state of the art" on a live problem, but they take time to arrange and must await the stated society meeting time. A journal, not connected with any single society, may at once collect and present what information there is on an important subject without waiting for the completion of a research or for a meeting date. Timely information, even if fragmentary, can be supplied by such a journal, and its publication will show up the gaps existing in the information and accelerate the filling of the gaps.

Hence Metals & Alloys plans to be immediately responsive to the needs of its readers. There will be found in the advertising pages a coupon, on which the reader may express his desire for the publication of information on any metallurgical subject within the scope of this journal. A goodly number of requests for information on one subject will be taken as a mandate to secure and publish the most up-to-date information available on that subject. The more fully Metals & Alloys becomes reader-edited, the better its mission will be fulfilled.

The exact scope of this journal is accordingly to be determined largely by its readers. In contrast to "trade journals," it will be concerned mainly with theory and practice in metallurgical science and technology. Its field is visualized as primarily that to which the term "physical metallurgy" is often applied, including the control of the properties of metals by alloying, by cold working and by heat treatment, their forming into usable shape by casting, rolling, forging, machining, plating, etc., and the determination of the suitability of metals and alloys for severe service under corrosion wear, high temperature, etc., and for special purposes such as in aircraft. It is not planned to deal directly with mining, milling and smelting of ores, methods of chemical analysis, or with problems of engineering design. But everything that affects the properties of metals and alloys or their suitability for industrial use, will demand attention. The original articles, correlated abstracts and ordinary abstracts in the field of scientific metallurgy in this and succeeding issues will deal with the subjects on which the editorial staff believes the users of metals need information. But "if you don't see what you want, ask for it."

Duplication of Effort

EVERY once in a while we hear some metallurgist say, "I understand a man in this laboratory and that laboratory are both working on the same problem. Society A and Society B both have technical committees dealing with the same subject. The Bureau of Standards, or the National Research Council, or somebody, ought to publish lists of research problems being studied so as to make it possible to avoid this wasteful duplication of effort."

This point of view is something like that which was rather prevalent in chemical circles twenty-five years ago when a professor, who had made a new chemical compound, would conclude his paper describing it with the statement that he "reserved the field" for future work. Nowadays it is more common for a paper to end with the hope that others may see fit to study the possibilities of producing other new compounds of that type.

The opposite point of view is that recently expressed by a research man who said, if he really wanted to get something done that he could rely on in the research game, he would put three separate crews at work and forbid them to consult each other at all so they wouldn't be biased by what the others thought. Then if all three came in with identical conclusions reached by different routes, he would be sure he had the answer.

The writer well remembers when he was a cub in the laboratory of Thomas A. Edison one summer. The "Old Man" asked for the solubility of some salt in some solvent. In order to be sure of his ground the writer looked it up in three different reference books, which gave figures that agreed pretty well, and promptly reported the average to Mr. Edison, who looked surprised and said "How did you get an answer so soon? Did you get it out of a book?" To the reply, "Three books gave that figure," he retorted, "I don't care how many books say so, go *do* it."

That the result, when it was done, agreed with what the books said did not make Mr. Edison feel that the time spent in finding out the facts in his own laboratory was wasted. (That the writer's salary was $12.00 per week is beside the question.)

On superficial consideration many more people will express the point of view of the opening paragraph rather than the Edisonian point of view. While it would be a pity to disregard entirely the work of others and to duplicate their work exactly, no research worker does use exactly the same methods as another. If two workers, tackling a problem by different methods and from different points of view, come out with experimental results that can only be interpreted to give the same answer, the certainty with which that answer can be used fully justifies the apparent "duplication."

If, as is usual, the two workers differ slightly in interpretation, each is incited to go further and see who is right, and ultimately the matter is settled.

If the work were all done in one laboratory, one man's interpretation would be likely to prevail in presentation of the work. If done in two laboratories, the matter is far more likely to be carried on till the facts prevail.

The endurance testing of steel is a case in point. Fifteen years ago, on the basis of Basquin's exponential theory, it was supposed that any stress, however small, if repeated a sufficient number of times, would ultimately break the specimen. The fact that one or two of Wöhler's original long time tests showed specimens unbroken after repeated stresses that should have broken then according to the exponential theory, was overlooked or ascribed to "experimental error."

When H. F. Moore, R. R. Moore, McAdam and others in this country, and Gough, Haigh, Lea and others in England all found an endurance limit for steel it was accepted as a fact notwithstanding the conflict with Basquin's conclusion, but it was not so accepted till it had been repeatedly shown by different observers. Basquin's work was far from fruitless, for it showed the best way to plot endurance data.

And who would have believed in the existence of the phenomenon of strengthening of an endurance specimen by understressing without detectable change in external dimensions, unless it had been repeatedly proven by different workers?

On important projects corroboration of results is more to be desired than "duplication of effort" is to be feared.

With present facilities for interchange of information through technical societies and scientific journals there is little difficulty in learning who is interested in the same problems you are, and in establishing contact with them.

Metals & Alloys will be glad to publish letters from its subscribers who wish to invite others interested in a given metallurgical problem to get in touch with them with the object of exchanging experiences, avoiding useless duplication and hastening the obtaining of reliable results.

Two Decades of Precipitation Hardening Alloys

By Zay Jeffries*

ABOUT twenty years ago Dr. Alfred Wilm discovered the heat-treatable aluminum alloy which, with some change in composition, is now known as "duralumin." The alloy is used in the wrought form. After mechanical working and annealing at 350° C., the tensile strength is about 25,000–30,000 lbs. per sq. in. The hardening and strengthening by heat treatment from this soft condition is accomplished in two stages. The first, now known as the "solution heat treatment," consists in heating to about 500° C. followed by rapid cooling. Immediately after this treatment the tensile strength is in the neighborhood of 40,000 lbs. per sq. in. By simply allowing material so treated to remain at ordinary temperature for four days, the tensile strength rises to about 60,000 lbs. per sq. in. This latter effect is now known as "age-hardening" when no separate heat treatment is required, and "artificial aging" when a temperature other than room temperature is used to produce the result.

As is quite generally known, duralumin was manufactured in small quantities before the World War in Germany, and during the World War in Germany, France, England and the United States. The most spectacular use was in the framework of Zeppelins, the satisfactory construction of which would have been impossible with any other known material. It would seem to be a fair conclusion that not only was the world production of duralumin during the first ten years after its discovery disappointingly small for a material having the strength of mild steel with only a little more than a third of the density, but apparently the unusual nature of the heat treatment had not stimulated other developments in aluminum alloys or in alloys of other metals. No one had offered a satisfactory explanation for the change in properties by heat treatment. In 1915 Dr. F. C. Frary found that lead-base alloys containing alkaline earth metals would harden when allowed to stand at room temperature after casting. No preliminary or solution heat treatment was used. This discovery was not stimulated by the duralumin art nor was any explanation of the phenomenon offered. It is now known, however, that the hardening of Frary's lead alloys, like duralumin, was caused by what is now known as "precipitation" or "dispersion." Such, briefly, is the history of the first decade of precipitation hardening alloys.

In 1919, Merica, Waltenberg and Scott, in the Bureau of Standards Scientific Paper No. 347, offered an explanation of the heat treatment phenomena exhibited by duralumin. The explanation was simple and bold. It was simple because it involved only the solution and reprecipitation of constituents, and it was bold because it attributed the age-hardening to the decomposition of a solid solution, whereas orthodox metallurgy demanded that such decomposition should be accompanied, not by hardening as in duralumin, but by softening. A proper interpretation of a mystery often provides support to our guiding principles, but in this instance we were provided with a new guiding principle. It is difficult to appraise the effect of the work of Merica, Waltenberg and Scott on the metallurgy of the last decade, but some idea of the scientific and industrial importance of alloys responding to improvement by heat treatment in part, at least, of the duralumin type, may be gained from the examples which follow.

According to Merica and his associates, at 500° C. aluminum dissolves more than 4% of copper as well as smaller quantities of other ingredients of duralumin, such as magnesium. The first heat treatment is required to allow the greater part of the alloying elements to go into solid solution in the aluminum. The rapid cooling is necessary to hold the ingredients in solid solution. The solubility decreases markedly on cooling, so at room temperature the solid solution of the quenched alloy is supersaturated. A hardness normal to the particular solid solution of the alloy obtains immediately after the quench. If at this stage the quenched alloy were reheated to 350° C. considerable softening would result and the microscope would reveal a large number of particles of hard compound, $CuAl_2$ in part, which could not have been detected before the anneal. The age-hardening was considered to be caused by the formation of sub-microscopic particles of inter-metallic compound. It was postulated that maximum hardness would occur with a definite size of these particles, and in order to obtain maximum hardness the precipitation must be allowed to proceed gradually near the *lowest* temperature possible. Considerable time is required to effect precipitation at a temperature which will produce nearly maximum hardness. The hardness sequence can be studied conveniently by heating freshly quenched duralumin at 200° C. The hardness rises for an hour or so, after which it decreases. The maximum hardness reached at 200° C. is not as great as that obtainable at about 150° C. but a longer time is required to develop the maximum hardness at the lower temperature. Finally when freshly quenched duralumin is cooled to liquid air temperatures no age-hardening occurs. This suggests the general thought that the temperature for precipitation must be selected within narrow limits for controlled results.

There was some opposition to the above interpretation but evidence soon piled up on all sides in support of the general theory. Hanson and Gayler soon announced that alloys of aluminum and magnesium-silicide responded to an appreciable degree to the duralumin heat treatment. Wilm had produced this effect by alloying magnesium with commercial aluminum but apparently it had not been appreciated by him that the silicon present as impurity in the aluminum was necessary for the result. Archer and the writer not only developed aluminum alloys and magnesium alloys with new properties using a "precipitation heat treatment" to produce the age-hardening, but the principle was used by them for thefirst time in determining the solid solubility curves of constitution diagrams by means of hardness measurements. Archer and the writer also used this conception in developing the slip-interference theory of the hardening of metals. In the portion of this theory dealing with precipitation or dispersion hardening, it was pointed out that myriads of small hard particles should markedly interfere with slip on the crystallographic planes by acting as "keys," and that a fine dispersion of hard particles within a metal crystal should result in greater hardening than atomic dispersion or solid solution.

---

* Consulting Engineer, Aluminum Company of America.

In 1924 Hanson and Ford reported the hardening of copper by adding about 0.7% iron, quenching from 1000° C. and reheating at 400–500° C. In 1925 Dean, Hudson and Fogler reported the precipitation hardening of lead-antimony alloys, the precipitation taking place at ordinary temperature after the quench. In both of the above cases the precipitation hardening is caused by the separation from solid solution of nearly pure metals, namely, iron and antimony. In duralumin the minute crystals separating from solid solution are intermetallic compounds.

Early in 1926 Sykes reported precipitation hardening in iron-tungsten alloys and later in the same year the work of Sykes on the iron-molybdenum alloys was reported. By adding 22% of molybdenum to iron, heating to 1425° C., and quenching, a Brinell hardness number of 215 was produced. No age-hardening was observed at room temperature, but on reheating for 24 to 48 hours at 600° C. a Brinell hardness number of 525 resulted. No carbon was present. This might be referred to as the first really hardenable alloy of iron without carbon. The heat treatment mechanism is essentially that of duralumin and different from that of ordinary steel. The iron-molybdenum alloy has no allotropic changes in the solid state. The molybdenum goes into solid solution at 1425° C. and a portion of it reprecipitates at 600° C. as minute particles of the hard compound Fe_3Mo_2.

In 1927 Corson reported on precipitation hardening of copper alloys. Silicon and nickel, when present in proportions to form nickel silicide, Ni_2Si, are very effective precipitation hardeners of copper. Gregg in 1929 reported on the addition to copper of seventeen separate metals or metallic compounds which, after suitable quenching and artificial aging treatments produce definite precipitation hardening effects Some of the hardness increases are very marked, and others are slight. Gregg also reported on six compounds which will produce substantial precipitation hardening in silver. Fraenkel and Schaller had previously shown that silver-copper alloys responded to the precipitation heat treatment, and Fraenkel and Nowack had reported the same for silver-copper-cadmium alloys.

Without attempting to enter into detail it can now be said that a considerable number of aluminum and magnesium-base alloys had been found which will respond to precipitation heat treatment. The art of heat treating light alloy castings has been developed in America. The principles underlying these processes are, however, only in part those of precipitation hardening. The commercial importance may be judged by the fact that in 1928 there were more than 25,000,000 pounds of aluminum alloy castings heat-treated in the United States alone. Also nickel, molybdenum, cobalt and zinc-base alloys have been found which may be hardened by applying the precipitation principle.

Certain work on iron-base alloys is particularly interesting. Sykes and the writer reported precipitation hardening superimposed on quench hardening of high carbon steel. Steel containing 1.23% carbon quenched from 850° C. in iced sodium hydrate had a Rockwell C hardness of 64 immediately after quenching. The hardness remains about constant if the steel is held at 0° C. If immersed in liquid air, the hardness increases to C 66 as a result of the transformation of some retained austenite to martensite. On standing at room temperature, however, the hardness further increases to above C 69, caused, it is thought, by the precipitation of iron carbide. A hardness of C 70.1 was obtained by quenching this steel from 850° C., immersing in liquid air, and then heating at 50° C. for 150 hours. Dean, Day and Gregg have recently reported that iron-nitrogen alloys age-harden at room temperature after quenching. They report that the blue heat effect which has for a long time been regarded as a property of pure iron may be caused by the solution and reprecipitation of nitrogen. Iron which had been nearly deprived of nitrogen showed only minor blue heat effects, and iron enriched in nitrogen showed exaggerated blue heat effects. Pfeil has found precipitation hardening effects in iron-carbon alloys containing only small percentages of carbon, and has reported similar indications in iron-oxygen alloys. He studied particularly the over-strain effect which he attributes to the precipitation phenomena. It thus begins to appear that many of the very strange and unusual properties of ordinary iron and steel are caused by solution and reprecipitation, as compounds, of one or more of the elements carbon, nitrogen and oxygen, sometimes in minute amounts.

Lest the inexperienced reader reach the erroneous conclusion that it is an easy task to discover precipitation heat-treatable alloys with new and marvelous properties, a word of caution is in order. There are severe limitations. There should be considerable solid solubility, but not too much. Gold, for example, is soluble in all proportions in silver in the solid state at all temperatures, and therefore cannot be induced to precipitate in fine particles necessary for precipitation hardening. On the other hand, iron is so slightly soluble in aluminum in the solid state that no appreciable precipitation hardening is possible. Similarly, many combinations can be eliminated as possibilities. In some cases there is considerable solubility but not enough difference in solubility between the melting point and the lowest temperature at which precipitation will proceed. These difficulties were so great as to practically preclude the development of precipitation hardening alloys before the work of Merica, Waltenberg and Scott. The relatively large number of such alloys which have been developed in the last ten years reflect not only the immeasurable help of guiding principles but also a tremendous amount of well-executed research.

To sum up, the first ten years after duralumin was discovered might be characterized as disappointing both from the standpoint of the growth of the duralumin industry and of the stimulation to general metal science and industry. At the beginning of the second decade after the discovery of duralumin an interpretation of the mechanism of its hardening provided guiding principles which have been very stimulating to general metal science and industry. So rapid and marked has been this advance that it can now be said that the general principle of improving hardness and strength of alloys by heat treatment is the precipitation hardening principle. The mechanism of the hardening of steel may now be regarded as a special case. In addition, the precipitation hardening principle is established as an aid to the study of the constitution of alloys, particularly when the precipitated particles are sub-microscopic. It seems also to have clarified the interpretation of mysterious properties of ordinary iron and steel. The principle is also being applied in the control of permanent volume changes in certain alloys. Finally, not only have there been new and improved alloys already developed for industrial use, but the application of the precipitation hardening principles and additional allied principles promises much for metallic products in the future.

Strategic Raw Materials

By Roger Taylor*

THE United States has such vast resources in raw materials and its industrial development and the ingenuity of its people are such that the average man overlooks the importance of certain raw materials and finished and semi-finished products which are imported from abroad. It was not until the World War that much thought was given to our dependence on foreign sources for certain commodities. In 1914 we soon felt the effects of the British blockade of Germany, not only because of the elimination of the Central Empires as markets for our raw materials, but also because it prevented the shipment to us, of certain things which we had been accustomed to buy from Germany. We felt particularly the effect of the cutting off of our supplies of dyes from Germany, because these, while representing a comparatively small tonnage and money value, were so essential to our great textile industries; while among the raw materials, our failure to receive from Germany the potash salts to supply our needs in fertilizers and chemicals was seriously felt.

As the war proceeded the supplies for the Allied Armies demanded ever-increasing ship tonnage—this demand was greatly expanded when the United States entered the war by the necessity of carrying to France our troops and supplies for them. The shortage of ocean tonnage was further accentuated by the German submarine campaign. Thus, while the seas and most of the markets of the world were open to us, we were faced by a dearth of such things as manganese, nitrates, rubber, sugar and tin, because ships to bring them from the country of their origin were either lacking or hard to get. This world war situation impressed forcibly on the minds of those who were familiar with it, the calamity which might result, were we ever in the future compelled to engage in a struggle in which those nations which control our sources of essential raw materials had interests at variance with ours or one in which our sea lanes were closed to us.

Quantities of finished and semi-finished products such as optical glass and others, are imported from abroad because the American superiority in mass production even when aided by tariff protection does not counterbalance the advantages of low-priced technical skill. If, however, we have the essential raw materials for the manufacture of such products, the ingenuity of our people and our industrial adaptability would permit the production of all such articles at a price were we allowed enough time to establish the new industries.

With raw materials, on the other hand, time works against us, where the materials are not produced in adequate quantities in this country. If our sources of supply are denied to us for any cause in a national emergency, we will find that as our need increases our supply will decrease until those stocks of imported raw materials which were in the country at the outset are consumed.

It is a duty of the War Department to consider what is to be done to meet our deficiencies in raw materials in case the nation is ever engaged in another great war. While efforts are being directed to insure against wars in future, the Army must continue the study of how to meet such an emergency should the efforts at prevention fail.

Under the National Defense Act the Assistant Secretary of War is charged with supervision of the procurement of all military supplies and the assurance of adequate provision for the mobilization of material and industrial organizations essential to war-time needs. In the fulfillment of this responsibility, he has carried on a continuous study of the raw material situation as it may affect his mission.

World war experience; studies of the present rate of consumption, production and importation; and estimates of future supply and demand, indicate that there are certain raw materials essential to the prosecution of war, which are not now produced in adequate quantities in the United States. These commodities have been designated "strategic," since they will influence in every way a serious conflict of the future.

The more important Strategic Raw Materials include Antimony, Camphor, Chromium, Hides, Iodine, Manganese, Mica, Nickel, Nitrates, Opium, Platinum, Quicksilver, Quinine, Rubber, Shellac, Silk, Tin, Tungsten and Wool. There are indeed other materials which might be added to this list but in most cases they are either involved in small quantities or can, without too great sacrifice of efficiency, be replaced by substitutes.

While the problem which each of the strategic materials presents is one single whole, the solution is only possible if the subject is divided into two parts, that is—one, the demand and possible source of supply for the agencies which would be directly involved in a war of the future, such as the Army, the Navy and that agency responsible for the construction of ocean transport; and two, the demands and supply for the continuation of the normal industrial activities of the country. The difficulties which are likely to arise in the industrial life of the country in war time will be due to the sudden creation of an expanded demand resulting from the needs of the fighting forces and in some cases to a contracted supply. The burden of military requirements is one which must have first priority, leaving the normal activities of the country in some confusion, unless the situation has been visualized and prepared for in advance.

If then the Army and Navy and other direct war requirements can be approximately determined in peace time, a sound basis will have been established from which plans can be made by the industries not engaged in the production of munitions, which should, when brought into use in war time, prevent confusion. The Assistant Secretary of War, through the Commodity Committees in his Office and the Supply Branches, is now studying the requirements in raw materials and endeavoring to determine how and from what sources these requirements can be met. It is hoped that as these studies develop they can be discussed with representatives of the industries which would be effected by a decreased ability to procure raw materials. It is hoped that in this way a combined plan can be worked out, under which all essential requirements, both military and civilian, can either be met or, failing this, under which the damage resulting from the shortage will be minimized.

---

* Major, Ordnance Department, U. S. A.

The character of the problems presented in planning to meet the military requirements for strategic raw materials and in attempting to visualize the influence on normal industrial activity resulting from meeting these requirements is illustrated in the following discussion of our position in the strategic metals which should be of interest to the readers of this magazine.

Antimony comes into the munition program as a hardener for lead, particularly in shrapnel balls and bullet cores, in bearing metals and as an essential constituent of the small arms primer in the form of the sulphide.

The domestic production of antimony as such is negligible and even in the form of hard lead it is small in comparison with the requirements. China is the principal source of cheap antimony, over 66% of our comsumption having come from China in 1926. The only nearby producer on which any reliance can be placed is Mexico. If we continue using antimony for all the purposes to which it is now put, it is doubtful whether the Mexican supply could be expanded to meet our war-time needs.

Even should China be anxious to furnish us with all of the antimony that we would require, the road from China is a long one to keep open and it might be that the tonnage necessary to bring antimony from such a distance would better be otherwise employed. Since our domestic antimony resources are so small there are only two alternatives which will make us safe against a shortage of antimony in a national emergency. These are the laying in and maintenance of a reserve stock of such a size as to make us independent of foreign sources for the probable duration of an emergency and the finding of substitutes of domestic origin which will replace antimony in its various uses. Since we know that some substitution certainly can be made, there would be no justification in either the War Department or the industrial interests of the country spending money for the purchase of such a stock until the field of substitutes has been fully studied, even were the stockholders in the Government and in the industrial corporations concerned prepared to appropriate funds for this form of insurance.

Investigations carried on by the Ordnance Department indicate that antimonial lead used in shrapnel balls and bullet cores can be replaced by Frary metal or some other type of hard lead. This at once eliminates a large part of the direct military requirements. It is believed that for many bearing metals those containing no antimony can be used with success. Military requirements can in this way be brought well within the domestic production and if study were given to the subject by those in industry who best know it, it would perhaps be found that on a necessity basis civilian requirements could also be brought within this quantity.

Chromium is used in armor plate, gun forgings and projectiles and for a variety of other purposes mostly in familiar commercial articles. During the World War the United States was a large producer of chromium but this production was made at high prices so that after the war it fell off to a great extent and in 1927 we only produced about 4% of our total consumption. From a commercial point of view, the United States is an unimportant source, but with outside supplies denied us, we could surely greatly expand our production.

In 1927, 57% of our chrome ore was imported from Rhodesia. Rhodesia is a long way off and in a foreign country and for these reasons dependence cannot be placed upon this source in a national emergency. The only nearby source outside of the United States which may be helpful is Cuba, which shipped us in 1927—17% of our consumption. Doubtless with improved methods of concentration, the Cuban production could be expanded.

In order that the United States shall be self-sufficient in chromium in war time three alternatives present themselves and for satisfactory results we may have to resort to all three of them. These alternatives are, first, the substitution of something else for chromium; second, the accumulation and maintenance of a reserve stock; and third, the stimulation of domestic production. For certain types of chrome-nickel steel forgings we may be able to substitute manganese-molybdenum steel forgings but the extent to which the situation can be relieved by this substitution has not yet been determined. It is hoped that the Bureau of Mines will be able to make an investigation of the chrome ore resources of the United States and thus establish the possibilities of domestic production in an emergency.

Manganese presents one of the most difficult problems of all the strategic materials. Its essentiality in the production of steel is such that steel itself becomes a strategic raw material from one point of view. Our domestic production is small in comparison with our total consumption, although hopes are held out that this production can be greatly increased. Still, however, until there has been a complete change in the domestic manganese situation, our total requirements cannot be met from within the country. The only bright spot to be considered in connection with manganese is the wide distribution of the possible sources of supply. Manganese can be produced in large quantities in India, Russia, Brazil and West Africa, in addition to the possible sources in the United States, Chile and elsewhere. Only the most adverse conditions would thus cut us off from all outside sources.

There is no present prospect of our being able to produce the large tonnages of steel desired of the necessary high quality by the use of a substitute for manganese. Substitution as a means of meeting the deficiencies which would occur with outside sources denied us is therefore not a solution of the difficulty. The possible means of avoiding a manganese famine are therefore the accumulation of a reserve stock and the augmentation of domestic production. It is probable that both of these methods will have to be used in a serious emergency. Until more certainty is felt, however, as to the possible domestic production, it will be difficult to say except within very wide limits, what size the reserve stock must have in order to represent adequate insurance.

The possibilities of domestic production is at the present time a controversial question, one group of individuals believing that with adequate protection the production of manganese in the United States can be expanded so that it will ultimately meet our needs and another group believing that this cannot be accomplished and that our reserves are so limited that every pound of manganese which is mined at home, instead of being imported from abroad, is whittling away the reserve which may some day be sorely needed.

Nickel for military purposes is principally used as a steel alloying material for gun forgings, armor plate and ammunition. We here find a problem which is simple to state but hard to solve inasmuch as nearly all of the nickel that we consume comes from Canada. Eighty-five percent of the consumption in 1927 was imported from Canada. The only other important source of nickel is in New Caledonia, although that island is a small producer at the present time.

The United States produces a negligible quantity of nickel from the electrolytic copper refineries. This supply was only 2.3% of our consumption in 1927 and is not capable of expansion. The only methods of protection against a shortage which suggest themselves are the replacement, in so far as possible, of nickel steel by carbon steel wherever this is possible, and the maintenance of a reserve stock. As in the other cases mentioned, the necessary size of a reserve stock cannot be stated until further study has enabled us to say to what extent other alloys can replace nickel steel in the various uses to which nickel steel has been put.

In making such substitutions, efficiency will have to be sacrificed in most instances, that is to say, that a 75-mm. gun of carbon steel which will have otherwise the same performance as a nickel steel gun of the same caliber would have to be heavier and so it is with other objects made from this alloy.

Platinum remains on the list of strategic raw materials although it is believed that at a price we can meet our requirements, even though we are shut off from sources outside of the United States.

The most important role of platinum in the munitions program is as a catalyst in the manufacture of sulphuric acid by the contact process and in the oxidation of ammonia to nitric acid, since nitric and sulphuric acid are essential to the production of both high explosives and propellent powders.

The United States produces an almost negligible quantity of platinum. The great sale of platinum jewelry in the United States during the last twenty years and the fact that only a very small percentage of this is lost or otherwise expended indicates that we have here a great reserve on which to draw, if we are willing to pay the price which will convert it from jewelry to industrial and scientific uses. There are only two important sources of platinum, one of which is in Russia in the Ural Mountains and the other in Colombia in South America. There has been talk of large resources of platinum near Johannesburg in South Africa. The production from this source, however, has so far been small. There is some production from the nickel mines in Canada as a by-product and this production will doubtless be increased as a result of a change in the character of the Canadian ore supply and a possible change in reduction methods. Many inconveniences will result from our inability to procure platinum from outside the United States, but they will not prevent or even retard our continued and augmented industrial activity in an emergency.

Quicksilver or mercury is of importance in the manufacture of fulminate for detonators, anti-fouling paint for ships and dental and medical uses. While the United States was once the major producer of mercury and was indeed able to supply the world with this valuable metal, mercury has been, to some extent, mined out and as a result Italy and Spain have become the world's chief producers. While there has been a greatly increased interest in mercury mining within the United States in the last few years, it is doubtful whether we could meet our requirements as they are now estimated from domestic sources, no matter how great were the need.

There is a variety of substances which have been used as a substitute for fulminate in commercial detonators but there has been none found so far which is considered entirely satisfactory for military purposes. It is believed that commercial concerns are applying some study to the production of a satisfactory anti-fouling paint, which will not contain mercury but it is not thought that the efforts up to the present time have produced a paint which would be as satisfactory for naval uses as the mercury paint now in use. All three possible methods of meeting the shortage are under consideration, that is to say, the stimulation of domestic production, the maintenance of a war reserve stock and substitution.

Almost complete absence of tin ore in the United States makes the tin problem another one that is more simple to state than to solve. The sources of tin outside of the United States are almost exclusively in the British and Dutch East Indies, China and Bolivia. If we are to be safe against a tin famine, we must determine to what extent we can go in substitution and then obtain reserve stocks enough to meet our essential requirements.

Tin is used for military purposes principally in food containers, solder and bearings. Curiously enough, for almost every use of tin a substitute can be thought of, but even when these have been made use of to the greatest extent, we will still have a large inescapable requirement. There are several materials from which food containers can be made in addition to tinned sheet steel, but will they serve our purposes? The weight and fragility of glass containers make them a very poor substitute to use in furnishing food to troops in the field. Paper and fibre containers appear so far not to have developed to a point where they are satisfactory for all purposes; black iron both plain and shellacked will serve for some things, but it is believed that until a great deal more has been developed in the way of substitute food containers, we will be unable entirely to get away from the tin can.

In some solders a reduction in the ratio of tin to lead can effect a saving. Furthermore, solders suitable for some purposes have recently been developed which are said to contain very small quantities of tin. In bearings it is thought that for many types certain hard lead alloys can replace the babbitts and bronzes. One therefore looks to both substitution and reserve stocks to insure against a famine in tin.

Although the United States has rather a large production of tungsten, we are not able to meet our requirements at home and it is almost certain that with the increased demand which war would bring domestic production could not be adequately expanded. China is the great source of tungsten outside of the United States and obviously it is a long haul from China. The possibilities of substituting molybdenum for a large part of our tungsten requirements may sometime solve our difficulties but this is something which awaits a great deal of study and experimentation because though there are many possibilities of substitution, we do not yet know what can be done on a quantity basis.

The great difficulty which is encountered in the study of the use of substitutes for the strategic metals is the fact that the metal for which substitution is to be made is, in most cases, the cheapest one which will accomplish the desired results and one cannot therefore expect that commercial concerns will go very far in the study of a substitution which would increase their costs if put into use under normal conditions. On the other hand, even where the Army with the aid of scientific laboratories has been able to determine that a certain substitution can be made, its introduction will involve a changed technique whose introduction during an emergency may cause loss of valuable time. If, however, cooperation is obtained from those industries which should be interested in the subject, methods will develop with time which will minimize the danger which would otherwise result from any stoppage of our continued flow of imported metals.

Demands of Chemical Industry on Metallurgy[1]

By B. D. Saklatwalla*

THE chemical industry has for its task the preparation of materials suitable for the needs of man from the resources of nature. The metallurgical industry does exactly the same thing and, although the principles governing the operations of both are based on chemistry, there seems to have been more or less a lack of understanding of the problems of the one by the other. Perhaps this may be due to the fact that the chemical industry is concerned mainly in producing its products in the right composition, with little regard to their physical state. The metallurgical industry, on the other hand, is responsible not only for the right composition but also for the correct physical properties, such as strength, ductility and hardness, suitable for the particular work which the metal is expected to perform. Further, it is demanded to-day that its products shall perform these functions not only under ordinary but also under extreme conditions, such as elevated temperatures, increased pressure and presence of corroding influences. Metallurgy thus born of chemistry is now striving to pay homage to its parent by furnishing materials of construction, enabling chemistry to advance processes with demands which could hardly have been met only a few years ago.

A metal or an alloy is produced by solidification of a molten magma. If there are various liquid constituents present in the magma solidification may take place selectively, but all constituents present in the liquid state will persist in the solid, since they all will be allowed to freeze to the ultimate product. This is very different from the processes of chemical industry where the ultimate products are won by crystallization or precipitation or distillation, and the mother liquor or filtrate or distillation residue is discarded, not entering the final finished product. This difference is due by no means owing to the metallurgist not being confronted with undesirable constituents in his molten metals before solidification. Such impurities are present and he is taxed with the ingenuity of distributing during solidification the undesirables in such a manner as to make them innocuous. We have the example of distribution of the harmful sulphides and phosphides in steel. Similarly he is expected to arrange his salutory constituents in the appropriate manner to the greatest advantage of the finally solidified metal. As an example we may state the distribution of carbides in steel. He does not stop at this but further controls the properties of his metals after their solidification by a redistribution and rearrangement of the constituents. He can by appropriate procedure even curtail the number of his solidified constituents by absorbing the one into the other by interdiffusion and solution. This is the technique of heat-treatment. He can further subject his solidified metal to extraneous diffusion of other compounds into its surface or body. This is the basis of the well-established procedures of cementation, case-carburization and calorizing, and also of the comparatively recently invented process of nitriding steel. The metallurgist therefore is called upon, after he has produced the right chemical composition, to endow his product with the requisite physical properties appropriate for some individual constructional problem. He therefore ceases at this point to be a chemist and is forced to think in terms of the physicist and the engineer.

The demands of the chemical industry on metals are in considerable measure different from those of the mechanical arts. While strength and elasticity are essential factors in designing equipment, the surface condition of metals, such as their resistance to erosion, corrosion and gas penetration, become factors of paramount importance. Further, heat conductivity, surface density, ability of brazing and welding deserve consideration. With the multiplicity of alloys available to the chemical industry, the question of price also becomes a big factor. The demands of the chemical industry, however, are not only more strenuous but also more varied than those of the mechanical industries. The problems of corrosion resistance, heat transference, et cetera, are entirely individual in each case and therefore the selection of the appropriate metal of construction for the individual requirement needs to be very judiciously effected, probably best by some test of the material under conditions as far as possible simulating actual service. The ills of the chemical industry erroneously grouped together under the general heading "corrosion" are of as varied and multifarious a nature as the human ills grouped under the name of "rheumatism" and the remedies applied just as inefficacious and ill-advised. Human nature takes the easy path of past experience and falls back on similarity of problem in previous cases. This similarity, however, is deceiving, as no two instances of chemical service are alike. Experience teaches us that slight differences in temperature, in concentration of solutions, presence of impurities even in minor traces, and of colloids, et cetera, entirely change the aspect of chemical action on metals to such a degree as to constitute total failure or success. Further failure due to chemical action is not proportionately progressive with time as in the case of mechanical failure, but when cause of failure once sets in its procedure seems to be rapid and erratic and not of the same duration under apparently similar conditions. It can be seen, therefore, that the demands of chemical engineering on metallurgy are very much more exacting than those of its other sister branches.

The above is in no way intended to convey that study of metals from the chemical corrosion standpoint should be confined to purely cut and try methods. On the contrary, a clear understanding of the procedure of corrosion and of the action of liquids, vapors and gases on metals at ordinary, or increased, temperature is of the greatest importance. Such understanding will afford us a foundation in evaluating selection of metals and in drawing the proper conclusions from test results.

Metals and alloys are bodies composed of microscopic structural aggregates and the exterior physical properties manifested by them are dependent on the size, configuration and interrelation of these aggregates. The physical engineering properties are derived from the cohesion in the aggregates and the adhesion forces in play at their boundaries. Hence constituents or impurities imbedded between the crystallite aggregates affect the properties.

---

[1] Presented before the Delaware Section of the American Chemical Society, March 20, 1929.

* Vice-Pres., Vanadium Corp. of America.

The corrosion properties of importance to the chemical engineer are more determined by the characteristics of the aggregates themselves and the skill of the metallurgist is directed towards procuring alloys whereby the constituents are homogenized as far as possible into a solid solution. It has been shown by Tammann and others that a metallic constituent can be made more chemically resistive by introducing in solid solution into it another metal chemically less active. Aside from this fact the introduction of another metallic element in solid solution homogenizes the structure, whereas if it were allowed to be present as a separate constituent would tend to accelerate chemical corrosion by galvanic action. As a criterion of chemical activity, Guertler suggests the heat of formation of the oxide or of the halogen compounds, the one with the greater heat of formation being the one more chemically active. *It becomes, therefore, the problem of the metallurgist to ennoble against chemical action the crystallite aggregate of a metal by finding the suitable metallic element which would more effectually resist the given chemical action and which would enter into solid solution in the original metal crystallite without producing an additional separate constituent in the metal.*

The action of a corroding agent on metals is no different from other chemical reactions, the same laws such as those of chemical affinity, determined by heat of formation and electrical potential, of mass action, and the like, are equally applicable in both cases. The velocity of reaction in corrosion phenomena is, however, very low compared with our experience of other chemical reactions. This lengthened period gives us the aspect of phenomena different in kind. Like all other reactions, the action of a liquid on metals is primarily dependent on the chemical "affinity" or reactivity of the various constituents present in the liquid-solid system. The mysteries of this chemical affinity have puzzled investigators since the time of the Greek philosophers up to that of Berthollet. Then, with the advent of the atomic theory of Dalton and the knowledge of thermochemical data, an era of a little more scientific elucidation was established leading up to the laws of chemical mass action by Guldberg and Waage. To these additions were made, especially on the mechanism of the action of acids on metals by Brunner at the beginning of this century, establishing the dependence of the attack not only on the rate of reaction at the contact surface of metal and acid, but also upon the rate of diffusion of the reacting components to the surface of contact. To these theoretical elucidations was added, towards the end of the last century, the concept of electrolytic dissociation by Arrhenius, Ostwald, van't Hoff and other workers and the picture of the action of acids on metals was further clarified. As a result of our latest knowledge of the structure of matter and of the configuration of the atom, we are ascribing chemical action between metal and liquid to the free surface energies of the atoms at the surface of the metal which are neutralized by the free energies of the atoms of the liquid in immediate contact with the metal surface. Whichever metal picture we may choose to accept we cannot claim that we have accomplished very much in enhancement of positive knowledge as to the operation of the force of chemical "affinity."

With the progress of civilization and the rapidly increasing use of ferrous and non-ferrous metals and alloys, the question of corrosion gradually became a tremendously important economic factor. With this condition a study of the involved phenomena became a pressing necessity. Various theories, especially as to the corrosion of ferrous metals, were advanced, such as the chemical oxide theory, the electrolytic theory and the chemical colloidal theory, but none were able singly to comprehensively explain all the corrosion phenomena. This is perfectly understandable when we consider that while corrosion phenomena are dependent primarily on three major factors, namely:

a—Chemical affinity between metal and corroding agent

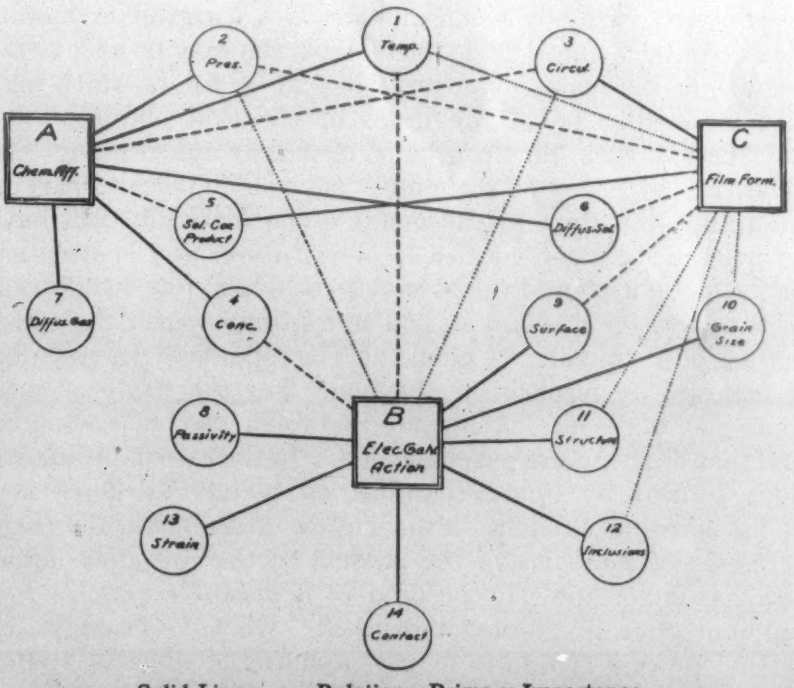
b—Electro-galvanic action due to differences of potential set-up in the system

c—Formation of protective films by the initial products of corrosion

that there are vast numbers of other secondary factors which affect one or the other or a combination of these major factors, that no single theory could satisfactorily explain all the phenomena. As such secondary factors may be enumerated:

1—Temperature
2—Pressure
3—Velocity of circulation of corrosive medium
4—Concentration of corrosive medium
5—Solubility of the product of corrosion in the corrosive medium
6—Diffusion of corrosive solution through protective film of corrosion product
7—Diffusion of gases evolved by corrosion reaction through metal
8—Conditions likely to favor or hinder passivity and over-voltage
9—Condition of surface of metal whether polished, matt or scratched
10—Irregular grain size of metal
11—Presence of various inhomogeneous constituents in metal
12—Presence of non-metallic impurities in metal
13—Strained condition of metal from heat-treatment or cold working
14—Contact with other metals and relative areas presented

In certain cases a single one of the secondary factors may be of controlling importance, but, in general, a multiplicity of them exert their influence simultaneously, thus making the corrosion phenomena complex as we know them to be.



Solid Line———Relation—Primary Importance
Dash Line – – – Relation—Secondary Importance
Dot Line ...... Relation—Casual Importance

Figure 1—Inter-Relation of Secondary to Primary Factors Affecting Corrosion

In Figure 1 an attempt is made to chart the secondary factors in their relative importance to the major factors of corrosion. The symbols and numbers shown in the chart are the same as given in the tabulation above. When a secondary factor is of controlling interest its connection with the major factor is indicated by a heavy line, if it is of less controlling interest a dash line connects it with the major factor, and if it is of only casual interest a dotted line is used. It should, however, be fully understood that this chart represents experience of average corrosion conditions and that the relative importance of the secondary factors to the major factors may change very substantially in particular individual cases. The chart is given for enabling one to form a picture of relative values, and it more or less brings out the fact that most secondary factors preponderatingly affect the primary factor B Electro-galvanic Action, as indicated by the large number of heavy lines running to B, a fact in keeping with our modern ideas of corrosion suggesting that most corrosion problems are of an electro-galvanic nature.

In the case of corrosion of metals by gases and vapors, similarly complex conditions exist. The factors of temperature and pressure assume extreme importance. Besides pure chemical action, the phenomena of adsorption, occlusion and diffusion accelerate the corrosion phenomena, and help not only the surface deterioration but also disintegration of the structure of the metal by intergranular penetration. We have a very marked example of this form of corrosion in the synthetic ammonia industry where the metal is subjected to the action of hot hydrogen and nitrogen gases. This type of gaseous reaction makes the highest demands on metallurgy as the material has to resist gas penetration at very high temperatures and pressures. Steels containing chromium with vanadium and in some cases with nickel have successfully met the requirements of this service.

Of the major factors enumerated above affecting corrosion, liquid or gaseous, the capability of the metal to form protective films seems to be of very great importance. It is assumed by some to be the prevailing cause of resistance to corrosion and that all non-corroding metals are believed to owe their inertness to the film formed. We have the very well-known examples of zinc and aluminum which, while chemically active metals, resist the oxidizing influence of the atmosphere due to the oxide film formed on their surface. In the case of other metals as iron the presence of a hydrogen film has been assumed, the hydrogen being evolved on the surface of the iron by the action of water vapor of the atmosphere. The films formed are not necessarily by chemical interaction with the production of a definite chemical oxide, but the oxygen may be held to the surface of the metal by adsorption and by forces which may not necessarily be of the order of chemical affinity. The thickness of such films can be of molecular dimensions. The physical properties of such films play an important part in affording protection to the metal. The ideal film will have to possess the same coefficient of expansion and contraction as the metal itself and would have to be impervious to diffusion of the corrosive medium and to be continuous over the entire surface of the metal. It should also be capable of regeneration if removed by mechanical abrasion. For the study of such films the works of Pilling and Bedworth and of Tammann and that of Evans are recommended. In the case of protective films formed by liquid solutions on metals by deposition of the corrosion product on the surface of the metal the characteristic of solubility of the product in the corroding liquid becomes important. If the product is insoluble more or less full protection is afforded the metal. We have examples of this in the case of lead in dilute sulphuric, of silver in hydrochloric, and of iron in concentrated sulphuric acids.

In the case of corrosion of metals by gases, another factor may become of importance, namely: the capability of a constituent or impurity of the metal to act as a catalyzer, accelerating the reaction between the gas and the metal, thus furthering corrosion. The purity of the metal and especially its cleanliness or freedom from inclusions becomes, from this standpoint, very important.

The metallic elements at the disposal of the metallurgist which he can utilize for engineering structures are relatively few. The basic metals of construction can be summed up as: iron, copper, nickel, aluminum, lead, tin and zinc. These basic metals are used as such or alloyed one with another. However, with the advance in our knowledge of the science of applied metallurgy, several other elements have been utilized as additive or modifying agents to the basic metals or alloys. As such additive metals may be mentioned: chromium, manganese, tungsten, vanadium, molybdenum, bismuth and cadmium. There is a further group of additive elements which, while not so commonly used, yet promise to widen metallurgical alloying possibilities. As such may be mentioned: magnesium, tantalum, columbium, titanium, boron, cobalt and beryllium. This classification is by no means rigid. Some of the basic elements in instances may function as additive and vice versa. For instance, copper in small quantities and nickel in comparatively larger amounts function as additive elements in alloy steels.

It had been very early recognized in the metallurgical arts that pure metals were not capable of fulfilling all requirements. This becomes very apparent to-day, especially in regard to the chemical industry. The requirements of chemical corrosion combined with pressure and temperature resistance cannot be found in the pure metals. It is for this reason that in recent years unusual activity has been displayed in the development of alloys to keep pace with the progress of chemical industry.

When chemical products were manufactured in small quantities and the units of apparatus were relatively small, the question of material for equipment was not so acute. In cases of extreme corrosion metals played a very insignificant part as the small units could well be constructed of stoneware, glass, porcelain and other non-metallic materials. The rapid increase of production made the use of small units uneconomical and larger units could not well be constructed of non-metals. The industry was then forced to call upon the metallurgist for alloys having the physical strength for large engineering structures and also possessing practically the non-corrodibility of the non-metallic materials. This call was responded to admirably, especially in the field of corrosion-resisting alloy steels. We are all well aware what this response has done to change the complex of the nitric acid and synthetic ammonia industries.

Attack of metals by chemical solutions and vapors is of a more complicated nature than can be pictured by a simple chemical reaction. The attack is generally not based merely on the solubility of a component of the metal in the corrosive solution. As the method of chemical attack does not differentiate very materially according to the nature of the corrosive medium, it would be more convenient, in the following, to group the discussion according as the metals are ferrous or non-ferrous.

The non-ferrous group of alloys has been used in the chemical industry in the form of pure metals or alloys much longer than the ferrous group. It consists of the copper, aluminum, tin, lead and nickel base materials.

The copper base alloys are suitable for the manufacture of equipment and containers for handling cold and dilute solutions of sulphuric, sulphurous and hydrochloric acids, and salt solutions of such acid radicals. These alloys are also useful for the construction of equipment handling mine waters, alkaline and tanning liquors and sea-water. Their usefulness, however, is limited when in the above-mentioned solutions oxidizing agents are present or they are required to operate at higher temperatures under mechanical load.

Aluminum as a metal has some very good properties for chemical resistance. However, concentration and temperature of the corrosive solution have a very great effect on the resistive properties of aluminum; therefore great care must be exercised in ascertaining these factors for a particular operation before adopting its use. Further, the purity and thermal history of the metal have great effect. For instance, aluminum that has been previously heated to 400–500° C. has been found to be more resistive to nitric acid and recent work of Professor Maas has shown that the temperatures of melting, rolling and heat-treating have a decided influence on the acid-resisting properties of aluminum. Further, these properties are very markedly influenced by slight amounts of impurities present in commercial grades, although such grades have been effectively used for handling certain concentrations of nitric acid at certain temperatures. The effect of temperature change is of a very high degree and therefore important. Similarly in the case of organic acids, such as acetic, butyric, stearic, oleic and palmitic, concentration and temperature have a tremendous influence, demanding judicious caution in its applications to these acids. It has been very useful in the preparation of foodstuffs and in the manufacture and transportation of acetic acid. With the advent of the Hoopes' process for refining aluminum, thus obtaining a metal of extraordinary purity, the future may see its wider application in fields where the presence of impurities of the present-day commercial grades has made it undesirable.

Tin has been used in the form of coating for other metals, mostly as tin plate for containers. It has been also used in the form of a heavier lining for copper vessels and tubes in the preparation of pharmaceuticals and foodstuffs. As the pure metal in the form of block tin, it forms essential material in the construction of distilling apparatus especially for distilled water.

Lead in the form of pure metal has played a very important part in the manufacture of sulphuric acid and in all leaching processes using dilute sulphuric acid as the leaching agent, or in precipitation processes where sulphuric acid is used as the precipitating agent, as in the manufacture of chromic and vanadic acids. Also, it is generally used where sulphuric acid enters into any chemical process, as in petroleum refining. It is also used for handling ammonia salts of organic and inorganic acids. In various electrolytic processes it serves as the anode material. Like aluminum its purity is also of great importance, as in certain cases unless it is highly pure its resistivity is of a low order. It lacks the characteristics of physical strength which is sometimes offset by the addition of other alloying metals, like antimony, but always accompanied by change in its resistive properties.

Nickel as the metal has been very widely applied in the foodstuffs industries and also in handling acetic acid in the presence of oxidizing agents. Alloys of nickel with copper and with manganese have been used for dilute sulphuric and hydrochloric acids and in contact with salt water. Alloys containing nickel are also eminently suitable for alkaline caustic and carbonate liquors and for hot or cold ammonia. Nickel-copper-chromium alloys with tungsten and molybdenum contents have been used for sulphuric and mixtures of sulphuric and nitric acids. Alloys of nickel have also been very useful against chemical attack in the household, and the laundry and dairy trades.

In the class of ferrous corrosion-resisting alloys there are two sub-divisions, namely: the cast-iron group and the steel group.

In the cast-iron group alloyed iron with small percentages of nickel has been commonly used for caustic pots. The caustic attacks the graphite lamellae in iron and any alloy which favorably changes the distribution of graphite is helpful. For acid-resistance the main iron alloys have been those containing high percentages of silicon, which contain from 13 to 17 % silicon and sometimes small percentages of other elements, such as manganese, aluminum and nickel. They have been marketed in this country and in Europe under various trade names. These alloys resist the action of acids well, especially of sulphuric and nitric and dilute cold hydrochloric, but have the disadvantage of lack of physical strength, absence of machinability, and brittleness. Where the acid action is combined with heat they have the further disadvantage of not withstanding sudden changes of temperature and of possessing low heat-conductivity. On account of the cast structure the walls of vessels, as in steam-jacketed kettles, have to be heavy, which further retards heat exchange in comparison with kettles of wrought alloys.

The field of high alloy cast irons has not been thoroughly investigated and compositions which have proved of merit in steels may be duplicated to advantage in cast materials. High manganese content iron of the type of Hadfield's steel and high chromium and chromium-nickel and chromium-copper and chromium-copper-silicon compositions have already been produced with high-carbon contents in the cast state for certain specific purposes of extreme service.

In the steel group within the past few years a considerable number of alloys have been brought out suitable for the requirements of the chemical industry withstanding the action of oxygen, hydrogen and nitrogen at high temperatures. Also, for acid-resistance in the cold, more types are available than before, so that the selection of material on the part of the chemical engineer becomes perplexing. Laboratory tests under laboratory conditions are less adequate for service criteria in the chemical industry than elsewhere, on account of the multiplicity of process variables that can exist. He must, therefore, rely on available service data, however meagre, and form his judgment on them with certain modifications dependent on his own peculiar conditions. This also impresses us with the importance of keeping complete records of behavior of the alloys in chemical service for future deductions.

Steels of medium alloy content have found considerable expansion in the chemical industry. Such steels containing nickel have been successfully used in caustic work and also in the manufacture of parts of equipment not subject to severe corrosion. In Europe chrome-nickel steel has been used in the catalyst chambers for synthetic ammonia but recently plants are being erected there with the use of chrome-vanadium instead of the chrome-nickel steel, indicating that the latter has not proved altogether successful. In this country the synthetic ammonia industry has very largely standardized on chrome-vanadium steel. Their use has been accompanied with marked lack of failure. They have the decided advantage not only of surface stability but of maintaining load-carrying capacity at over 500° C. temperature. Chrome-vanadium composition has the further advantage that it is a steel eminently suitable for casting large ingots such as would be required for producing the one-piece forged catalyst chambers. Not all steels are capable of being successfully cast in large ingots. The success of chrome-vanadium steel in the synthetic ammonia industry has paved the way for its use in oil refinery work where high temperature and pressure and gas penetration have to be combated. Also, these properties promise in the future to make its use for high pressure boiler work general. Chromium-copper steels, either with low or high percentage of silicon, have come to the fore lately. They have some very excellent heat and acid-resistant properties. The field of the low alloy corrosion-resistant steels has not yet been exploited and promises a very fertile field for investigation by the chemical industry. Such alloys have the advantage of easier fabrication and cheaper material cost as compared with the high alloy steels.

The tonnage of high alloy steels going into the chemical industry is daily increasing. This is due to the ability of the metallurgist to meet the specifications and more fully understand the requirements of the chemical trade. The most useful of this type is the group of high-chromium steels. Such steels have changed the aspect of the nitric acid industry, not only from the standpoint of manufacturing equipment, but also from that of shipping containers. Such steels can be produced in all forms of fabrication as plates, sheets, tubing, forgings and can also be welded. However, great care and extreme caution are necessary to remove the effects of fabrication by the requisite heat-treatment. It should also be remembered that many such steels are air-hardening. If properly treated and judiciously handled, these steels are capable of excellent service and portend to change the aspect of various chemical operations as they have already done for the nitric acid industry. The addition of nickel confers added fabricating properties to such steels and the addition of copper meets the requirements of certain types of corrosion. In order to offset their lack of machinability, zirconium sulphide has been added to them which has overcome this difficulty very successfully. These types of steels have not only entered the field of the heavy chemical industry but have also found wide application in the preparation of foods, soft-drinks, cafeteria and kitchen equipment, laundry machinery and the like. The type containing 18% chromium and 8% nickel deserves special mention on account of its future possibilities in the chemical industry.

As special cases of high alloy steels for extreme conditions may be mentioned the European alloy B. t. g. and the alloy newly described by Field. The B. t. g. alloy has successfully met various extreme corrosion conditions and the Field alloy is supposed to withstand the action of hydrochloric acid, a great desideratum of the chemical engineer. These alloys have the following approximate analyses:

	B. T. G.	Field
Nickel	58%	57%
Tungsten	4%	...
Manganese	1.5%	3%
Carbon plus Silicon	0.5%	0.5%
Iron	24%	20%
Chromium	12%	...
Molybdenum	...	20%

In order to give a general view of the field of metals applicable to the chemical industry, a table has been presented as Figure 2. This is not intended to serve as a comprehensive list for selection of materials for specific purposes but only as a guide to the entire complex field. Also, the ordinary materials for structural purposes that are only resistant to atmospheric corrosion have not been included. Detailed lists and tables can be found in the publications of Hatfield, Mitchel and the very excellent paper of Jerome Strauss read at the last convention of the American Society for Steel Treating at Los Angeles which can be profitably referred to.

To meet the requirements of the chemical industry the metallurgist is not only called upon to produce the requisite composition and physical structure of metals but also to solve some of the problems of a more mechanical nature. For instance, in high pressure work the question of seams either by welding or riveting becomes acute. The metallurgist has offset this deficiency by altering his metal composition to suit the possibility of being able to forge a container in one piece. Similarly he has developed suitable analyses of welding rods which would prevent corrosion at the welds owing to dissimilarity of materials. He is also sometimes obliged to change his composition in order to obviate quenching in heat-treatment. Strains in metals are the sources of distortion and corrosion and it is therefore preferable to meet the requirements of a problem with an annealed or normalized equipment in place of a quenched one. Similarly in some cases it is essential that a metal revert after temperature change cycles to its original dimension. The metallurgist by his alloying technique has been able to accomplish this. The application of metallurgy to such mechanical problems becomes of great help in designing and constructing equipment such as valves, meters and the like. In some chemical equipment the metallurgist is required not only to furnish corrosion, temperature and pressure resisting material but it is also demanded of him that such material must also combine the qualifications of a good bearing metal. The knowledge of adequate heat-treatment, not only of the original metal but of the finished and fabricated equipment, in some cases becomes a very important factor and therefore development of processes for heat-treating large size units of chemical apparatus should be studied very assiduously. Welds have been disastrous not so much from their inherent weakness but from alteration of structure brought about by the welding temperature in the adjacent metal. Heat-treatment of finished equipment could be the only remedy for this defect. The advance made by the metallurgist in developing steels which would have the right characteristics of freezing when cast in very large size ingots and in the subsequent soaking and fabrication processes of such ingots portends to materially

Figure 2—Typical Corrosion Resistant Alloys

Name of Metal or Alloy	Nominal Chemical Composition (Per cent)										Tensile Strength 1000 Lbs./Sq. In.		Field of Application
	C	Si	Mn	Ni	Cr	Fe	V	Cu	Al	Zn	Cast	Wrought	
Pure Aluminum		0.2				0.5		0.1	99.2			12–22	Acetic acid, nitric acid, foodstuffs
Manganese Aluminum		0.3	1.5			0.5		0.2	97.5		16–20	14–26	Sea waters, natural waters, brine
Pure Copper								99.8			20–22	25–30	Sulphuric acid, hydrochloric acid, alkalis, salts
Brass								67		33	35–45	45–80	Sea water, natural waters, salts
Everdur		4.5	1.0					94.5			50–60	55–140	Similar to copper and brass
Pure Nickel	0.1		0.1	99.2		0.4		0.2				60–130	Sulphuric acid, hydrochloric acid, foodstuffs, alkalis
Monel	(*a*)	(*a*)	2	67		2		27			65–75	65–140	Similar to pure nickel, also sea water
Nichrome	1	0.5	2	65	15.5	16					50–60		General high temperature processes
Ni-Cr-Steel	0.15	0.20	0.30	4.0	0.75	(*c*)						70–150	Ammonia synthesis, oil refining
Cr-V-Steel	0.20	0.20	0.75		1.00	(*c*)	0.15					70–175	Ammonia synthesis, oil refining, steam service
Copper Steel	0.25	0.02	0.50			(*c*)		0.90				70–75	Oil industry (field service in natural and salt waters)
Stainless Iron	0.10	0.30	0.40		12.0	(*c*)						60–240	All of this group find application in the General Chemical Industry, oil refining, nitric and mixed acids, acetic acid, foodstuffs, dyes, alkalis, acid and neutral salts, high temperature processes, etc.
Chrome Iron	0.10	0.60	0.40		17.0	(*c*)					60–100 (*d*)	80–200	
Nickel-Chrome Iron	0.15	0.30	0.40	8.0	18.0	(*c*)					70–110	90–250	
Ni-Cr-Si-Steel	0.30	2.5	0.50	25.0	17.0	(*c*)						100–200	

(a) C + Si −0.5 (Wrought) or 1.5 (Cast).
(c) Remainder (Including Impurities).
(d) Somewhat Higher Carbon when Cast.

help chemical processes. In order to meet price competition the chemical industry is obliged to go to immense size units and some processes operating at high temperature and pressure have demanded one-piece forgings made from very large ingots. The oil refining and the synthetic ammonia industries are already reaping the benefits of such ingot processes.

In the treatment of refractory minerals, waste residues, metallurgical slags and the like, considerable attention has been devoted to the possibilities of recovering values by means of chlorination at high temperatures. Such processes would also furnish an outlet for large quantities of chlorine gas. The engineering of suitable equipment for this service becomes quite a problem as materials that will withstand the action of chlorine are few and those few do not possess the necessary qualifications of mechanical strength and fabricability. The development by the metallurgist of metallic alloys of adequate strength that will withstand the action of chlorine compounds would be very welcome. Similarly there is still a great need for alloys resistant to hydrochloric acid in various strengths.

The processes of covering metals with a superficial layer of a non-corroding metal have played a great part in the chemical industry. Lead coating and dipping are familiar to every chemical engineer, so are galvanizing, tin-coating and the various processes of spraying, as also the thermal processes such as calorizing. In recent years considerable advance has been made in the processes of depositing metallic surface layers electro-galvanically. Experiments are continually in progress for improving processes of electroplating tin, zinc, lead, cadmium and chromium. Probably the greatest advance has been made in chromium plating. Possibilities are also there of developing plating with such chemically inert metals as tantalum.

In very many cases the designer and operator of chemical equipment can aid the metallurgist by not subjecting the materials of his equipment to unnecessary drastic service. In direct fired apparatus the oxidizing or reducing nature of his flame and the sulphur content of his fuel will be determinative factors in the life of the equipment. Uneven heating also helps to produce strains and incipient cracks which start corrosion and disintegration. In certain operations filtrates and waste liquors can be effectually neutralized by lime before feeding them to pumps or other equipment. The designer can also, by the selection of a little costlier material, assure more uninterrupted operation, balancing his original cost against replacement cost, interruption of service, lack of production and consequent loss of profits.

The art of metallurgy is very old, the science of metals is young, but the science of applied metallurgy is only in its infancy. The progress of applied metallurgy depends very greatly on understanding the various and many factors which together make the problem and it can be rapid only if the user of the equipment built of metals will discuss the details of his conditions with the producer of the metal. One little factor omitted might be sufficient to cause failure of the particular alloy or metal recommended. Cooperation in this instance, like elsewhere, is the foundation of success.

International Standardization to Be Considered

James A. Farrell Announces Industrial Leaders to Direct National Standardization Activities

A far-reaching development in national industrial standardization activities will have its inception July 9th when railroad and utility presidents and other first line executives representing nine of the nation's greatest industries meet at the headquarters of the American Standards Association in New York to take over from scientists and engineers the reins of direction of the national standardization movement, according to an announcement made today by James A. Farrell, President of the U. S. Steel Corporation and, since 1925, chairman of the Advisory Committee of the American Standards Association. The occasion will be the organization meeting of the first board of directors of the American Standards Association, a national federation of 40 technical, trade and industrial organizations and government departments.— Recognition by industrial executives of the tremendous savings to be made through standardization led to the recent reorganization of the Association to place control of standardization policies into the hands of industrial leaders.

The Board of Directors will include in its membership Matthew S. Sloan, President of the New York Edison and affiliated electric companies; L. A. Downs, President of the Illinois Central Railroad; Bancroft Gherardi, Vice-President of the American Telephone and Telegraph Company; F. E. Moskovics, President of the Improved Products Corporation; Quincy Bent, Vice-President of the Bethlehem Steel Company; Howard Coonley, President of the Walworth Company; R. J. Sullivan, Vice-President of the Travelers Insurance Company; C. L. Collins, President of the Reliance Electric and Engineering Company; and George K. Burgess, Director of the United States Bureau of Standards.

One of the most important questions to come up before the Board of Directors tomorrow is that of American participation in international standardization activities. The International Standards Association, an affiliation consisting of the national standardizing bodies of Austria, Belgium, Czechoslovakia, Denmark, Finland, France, Germany, Holland (with reservation), Hungary, Italy, Norway, Russia, Sweden and Switzerland, has formally invited the American Standards Association to its membership. Although the American body was represented in the organization of the International Standards Association, membership has been kept pending to await the action of the Board of Directors. The International Standards Association now maintains an office at Baden, Switzerland.

The full control of national standardization policies, since the organization of the American Standards Association as the American Engineering Standards Committee in 1919, has been entirely in the hands of engineers and scientists. The reorganization which led to the formation of the Board resulted from the increasing interest of industrial executives in national standardization work. The first meeting of the board is expected to be followed by an intensive campaign to finance national standardization activities on a larger scale than heretofore.

X-Ray Metallography in 1929[*]

By George L. Clark[†]

Table of Contents

1. The Nature of X-Rays. 2. Radiography. 3. The Diffraction of X-Rays by Metals and Alloys. 4. Experimental X-Ray Diffraction Methods. 5. Results of Analysis of Ultimate Crystalline Constitutions of Metals. 6. Analysis of Alloy Systems. 7. The Determination of Grain Size, Internal Strain, Purity and Other Properties. 8. Analysis of Fabrication of Metals and Alloys. 9. The Analysis and Control by X-Rays of Heat Treatment and Recrystallization. 10. The Structure of Electrodeposited Metals. 11. Practical Applications of X-Ray Methods to Problems of Metallurgical and Mining Industry.

1. The Nature of X-Rays

METALLURGY as an art and as a science has as ancient and honorable a history as any of man's efforts in craftsmanship. Centuries of empirical progress gave rise to chemical and physical sciences of metals as craftsmen discovered better methods of mining, refining and fabricating these materials so essential to civilized well-being and to warfare. The explanation of practical behavior was sought in increasingly penetrative searchings into the ultimate units from which metals and alloys build themselves. The invention of the microscope led to the disclosure of characteristic details of fine structure hitherto unsuspected and as a result a great and indispensable science of rational identification has given remarkably complete information, at least for polished surfaces and for grain sizes or structural discontinuities down to the limit of the microscope and of visible light. A step further in recent years has been taken in the employment with quartz lens microscopes of ultra-violet light, the wave-lengths of which are shorter beginning at the end of the visible spectrum at about 3900 A. U. and extending down to 300 A. U. or lower. It follows that matter should disclose further details of fine structure when examined (of course photographically) with radiation such as the cadmium line at 2750 A. U. Next lower in the band of electromagnetic waves and exactly like visible or ultra-violet light (as are also cosmic rays, gamma rays from radioactive substances, infra-red and radio waves) except in wave-lengths, are X-rays which have been, since their discovery by Röntgen in 1895, generated and experimentally measured over a range from a few hundredths of an A. U. up to well over 100 A. U. If then an average X-ray wave-length is about 1/10,000 as long as that of yellow sodium light, it may be predicted that X-rays will penetrate matter opaque to ordinary light and that they should somehow be associated with a far finer state of subdivisions of matter upon which the rays infringe or which they traverse than is apparent by microscopic examination in visible or ultra-violet light. This twofold prediction, based upon a thorough knowledge of the nature of X-rays, has been completely verified. X-rays do penetrate matter and are differentially absorbed depending upon the kind of the material in the path. Thus a shadowgraph of any object may be registered by the emergent rays. And because X-rays have wave-lengths of the same order of magnitude as the spacings between atoms and molecules primitively constituting all matter, an interaction can and does take place to the end that the term super-supermicroscope is in a sense synonymous with characteristic X-ray diffraction which reveals the unit architectural plan by which all solid materials are built. Since, therefore, X-rays penetrate metals and reveal gross structural differences, and since they are diffracted by metal crystals or aggregates depending upon the arrangement of atoms in space, the double science of X-ray metallography has become inevitably a new and powerful contribution to metallurgical science and industry. Its results, because they are soundly fundamental, are immeasurably valuable from a practical manufacturing standpoint. It is the purpose of this paper to present a concise account of the various phases of the science which, though still in infancy, has achieved for the most part in scarcely more than five years the cognomen of an indispensable tool in research, testing and specifications and in general in removal of metallurgy from empiricism.

2. Radiography

Medical diagnosis by means of radiography has become so important and well known to the layman that little comment is required. The location of foreign bodies, bone fractures, internal tumors, and lesions of all kinds even in the softest tissues has become an indispensable part of medical practice. The science depends upon the penetrating power of X-rays and the differential absorption by substances of various kinds in the path of the beam. Mention should be made of the development of extraordinary technic in bringing various organs into relief by injection of gas or iodized oil or by the ingestion of barium or bismuth (both heavy metals with great absorbing power for the rays) in the alimentary canal.

The technic for preparing radiographic pictures is comparatively simple. A tungsten target X-ray tube of the Coolidge hot-filament type is ordinarily employed. The filament is heated to incandescence by a separate circuit and this constitutes the cathode in the high tension circuit, with the target as the anode. A closed-core, oil-immersed, high tension transformer which may produce up to 300 kilovolts is almost invariably the modern equipment. The alternating high tension current is rectified by mechanically rotating discs or by vacuum-tube Kenotrons. The targets may be water-cooled by an insulated circulating system and thus enable the passage of large currents through the tubes. Since radiographic exposures are usually of short duration, X-ray tubes of the universal type in which the targets become hot, are ordinarily employed. The object which is to be radiographed is placed at some distance from the tube so that the rays proceeding from the focal spot on the target are essentially from a point source. Radiographs are merely shadow pictures produced by radiation travelling in straight lines from a point source. It is essential that the photographic film be placed as near to the object as possible in order to prevent distortion. The film is enclosed in a cassette with intensifying screens of calcium tungstate. On account of the fact that some of the radiation is scattered and reflected, as well as passing through or being absorbed in the object, thorough protection with sheet lead on the back and edges of the film is required. The factors which are involved in a radiograph are, therefore, as follows:

---

[*] Part 1 of an article to be published in three parts in subsequent issues.

[†] Professor of Chemistry, University of Illinois.

1. The percentage of energy absorbed depends on the wave-length of the radiation, the thickness of the material, its density and atomic weight. For a given wave-length or voltage the absorption will increase, or the penetration decrease, with the thickness of material and with its atomic weight. For example, at 200 kilovolts the thicknesses of metals through which radiation may penetrate with equal emergent intensities as observed on a fluorescent screen are 20 mm. for copper, 40 mm. for iron and 300 mm. for aluminum; by photographing on a duplitized film between two intensifying screens the thicknesses are, respectively, 60, 100 and 400 mm. In Figure 1 is shown the radiograph of a series of metals welded together, respectively, ingot iron, cast iron, brass, copper and ingot iron. It is evident that cast iron is most easily penetrated by the radiation and copper absorbs the most energy. The defects in the welded strip will be discussed later. In Figure 2 are reproduced curves showing the correct relationships for radiographs of aluminum and iron between thickness, milliampere-seconds, and kilovolts on the X-ray tube. For these values, determined by Dr. Otto Morgenstern in the laboratory of Siemens-Reiniger-Veifa, the distance from focal spot to film was 40 cm. and two intensifying screens were used.

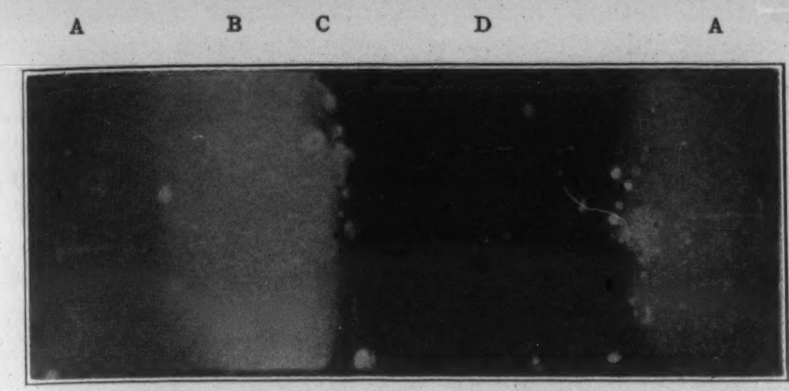


Figure 1—Radiographs of Welded Metals of Equal Thickness Showing Relative Transparencies to X-rays
A. Ingot Iron B. Cast Iron C. Brass D. Copper

2. If an object made of materials of different densities, or containing inhomogeneities, or a homogeneous material of varying thickness, is subjected to radiographic examination the film will show upon development densities corresponding to the transparency of the various thicknesses. Thus bones will appear light on the photographic negative, and gas pockets in cast steel as dense spots.

3. Distortion is likely to occur in the projection of inhomogeneous areas on the photographic film. Thus if there are two equal areas which are more transparent to radiation than the surrounding material, the one farther from the film will produce a larger area on the film. This difficulty is reduced to a minimum by placing the film as close to the object as possible and by increasing the distance from focal spot to film. There are practical limitations to the latter adjustment since the energy received by the surface of the film varies inversely as the square of the distance and the time required for exposure is thus greatly affected. Experience is required in the matter of adjusting the X-ray beam, the object and the film in alignment so that the projected image will correspond exactly to the original in size and shape. This is a more serious matter in medical diagnosis, of course, than in the examination of metals or other materials where the primary purpose is to discover the presence of any defect. However, the depth and angular disposition of an inhomogeneity in such materials may be ascertained much more certainly by stereoscopic radiography. Two radiographs are made in each of which the tube has been shifted about 1.25 in. on either side of the center of the object. The two films are then viewed in the stereoscope which fuses the two pictures into one with the appearance of three dimensions.

Upon such general principles as these which have just been outlined, has been constructed the science of metal radiography. For just as the inside of the opaque human body may be observed on the film or on the fluorescent screen by virtue of the differential absorption of penetrating X-rays and without damage, so also may any metal object be radiographed for the purpose of determining the gross structure and the presence of any inhomogeneity or defect. The immeasurable importance of this information is evident in terms of the satisfactory behavior or failure of metal objects of practical utility and of the

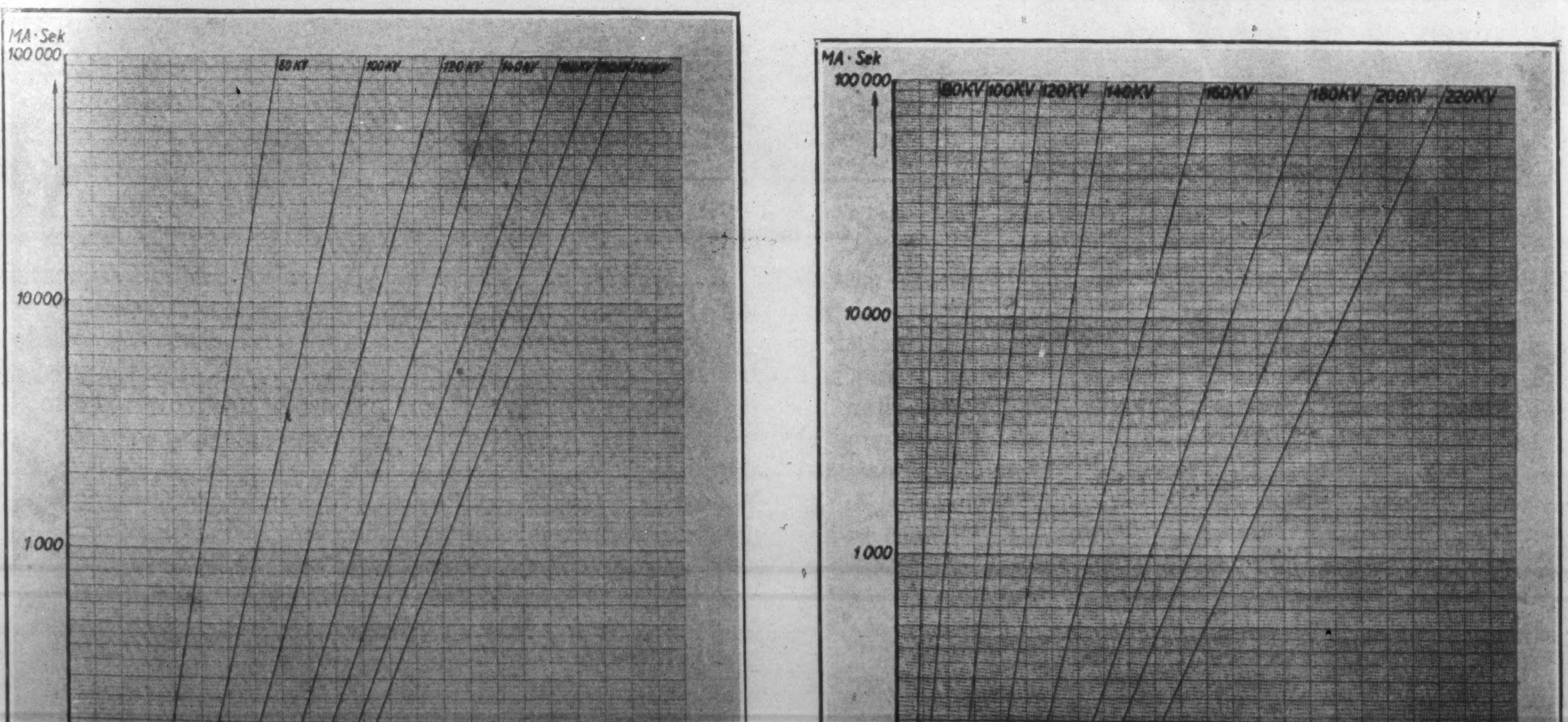


Figure 2A

Figure 2B

Figure 2—Radiographic Exposure Times for Aluminum and Iron as Functions of Thickness and Tube Voltage. Distance, Focal Spot to Film, 40 Cm. Two Intensifying Screens (Morgenstern)

safety of human life which is so frequently involved. The following enumeration of examples of metal radiography is but a fragmentary indication of the value of this method of testing and specification and of development and control of manufacturing technic.

1. Metal Castings. This is the most important application of X-ray radiographic diagnosis simply because of the wide use of castings and because of the uncertainty of gross structure with empirically developed foundry practice. The following defects may be radiographically detected on the interior of castings without in any way destroying or marring the specimens, although the diagnosis may be confirmed by "post mortem" incisions:

- Gas cavities
  - Due to gases liberated from the hot metal
  - Due to gases from the mold
- Sand inclusions
- Slag inclusions
- Pipe or shrinkage cavities
- Porosity
  - Due to small gas cavities
  - Due to small shrinkage cavities
- Cracks
- Metal segregations

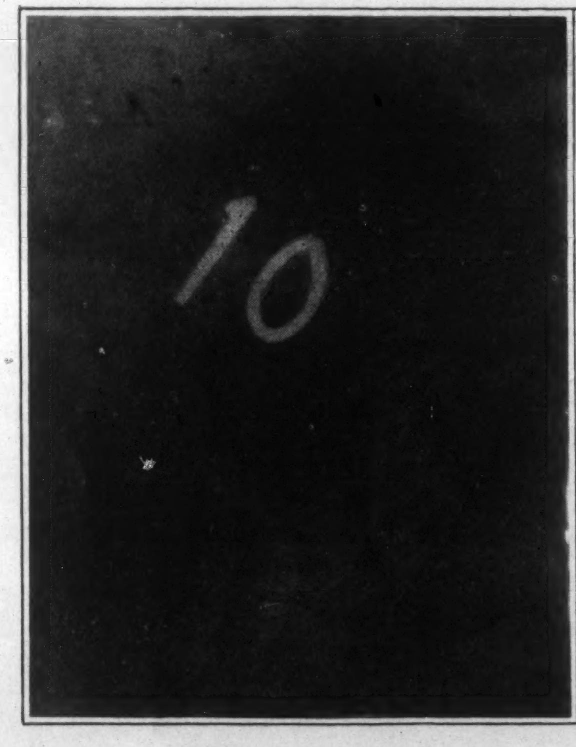


Figure 3—Radiograph of Cast Steel Showing Numerous Defects

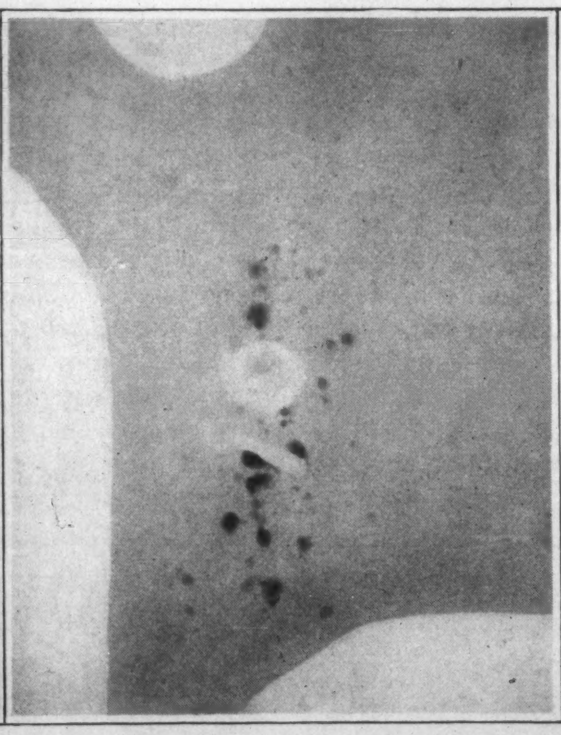


Figure 4—Radiograph of Cast Steel Showing Gas Inclusions

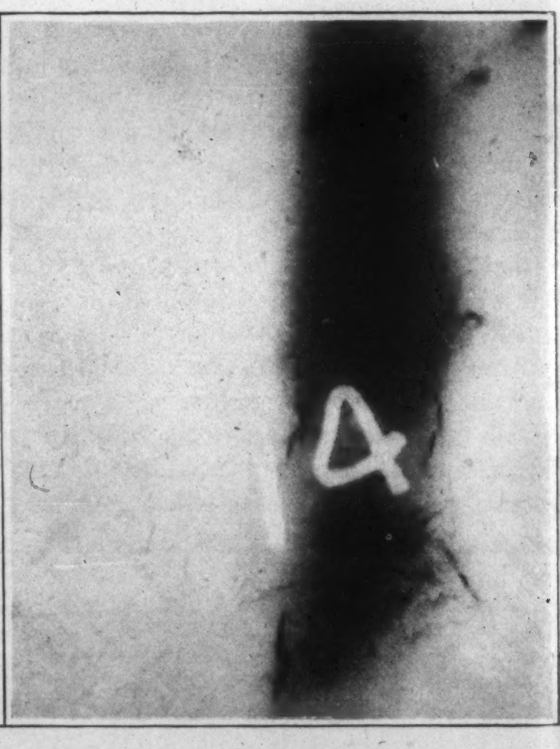


Figure 5—Radiograph of Cast Steel Showing Internal Cracks

Figure 3 shows the interior gross structure of a steel casting 1.25 in. thick which is characterized by every type of defect noted above, particularly gas cavities, non-metallic inclusions and shrinkage cavities. The photographic reproduction is a negative and the spots of smaller absorbing power show up darker than the surrounding metal. Figure 4 shows typical gas cavities in cast steel 1 in. thick and Figure 5 demonstrates with remarkable clearness the presence of internal cracks entirely unsuspected in cast steel 1.5 in. thick. These radiographs have been supplied through the generous cooperation of Dr. H. H. Lester of the Watertown Arsenal, the leading authority on metal radiography.

It is now possible with commercially available equipment to radiograph satisfactorily 3.5 in. of steel, while the Woolwich Arsenal in England reports penetration of 4.5 in. of steel showing an internal flaw 0.3 in. in diameter. The limiting thickness of metal is at present determined by the inability of available X-ray tubes to withstand voltages higher than about 280 kilovolts.

The value of the X-ray method of inspection of castings to insure soundness and safety in operation is readily apparent. The method may seem too expensive, to utilize in the examination of every piece, but even in such cases it may be employed to tremendous advantage in the derivation of a proper foundry technic and changes in the design of core and mold or in the process of gating. Many progressive foundries have adopted this practice, although the great majority still cling to the old empirical methods and uncertainty whether a casting will survive or fail. On the other hand it is the part of wise economy often to radiograph every unit of cast metal in an installation or every piece which is intended for expensive machining operations. An outstanding example in which extensive radiographic tests were used as specification for acceptance of parts is that of the high pressure steam installation in the Edgar power plant of the Boston Edison Company at Weymouth, Massachusetts. The pipe and fittings for the 1200 pound steam line and the cast shell of a 3000 kw. steam turbine were all examined and many rejections were made upon the basis of the radiographs before acceptance. The justification lies in the fact that not a single failure or break of any kind has occurred since installations even though the conditions represented are extreme. Examples of this type are being multiplied rapidly at the present time and radiography must be considered an indispensable and thoroughly scientific testing and control method in the foundry industry.

2. Welds. Closely allied to the problem of testing metal castings for soundness is that of welds. Here again there is no positive assurance by the usual methods that a weld has been made perfectly. With the agency of X-rays the smallest defects such as pipes or gas inclusions are indicated directly with the result that a vast improvement in the technic of welding has taken place in the space of a very few years. Welds are now made with certainty of safety where they would never have been attempted previously. Figure 6 shows the actual condition of a typical weld which appeared perfect on the outside. Reference has been made already to the imperfections of union and of inclusions in the welded metals in Figure 1. The radiography of welds in locomotive parts subjected to vibrations and stress is widely used, particularly in Germany. The writer recently advised the installation of an X-ray plant by a large manufacturer for the continuous inspection of welded rod to be used in the drilling of oil wells. Here is a case where these rods hundreds of feet long depend entirely upon the strength of the weakest welded joint, for with a break the rod falls to the bottom of the well. Consequently the manufacturer did not dare to market the product without the assurance of sound joints. Since the rodding was only about 1 in. in diameter it was found possible to use visual inspection with a fluorescent screen as the welded pieces moved along on a belt. The inspector was protected from the radiation by observation of the screen by means of a series of mirrors arranged in baffle fashion through heavy lead glass.

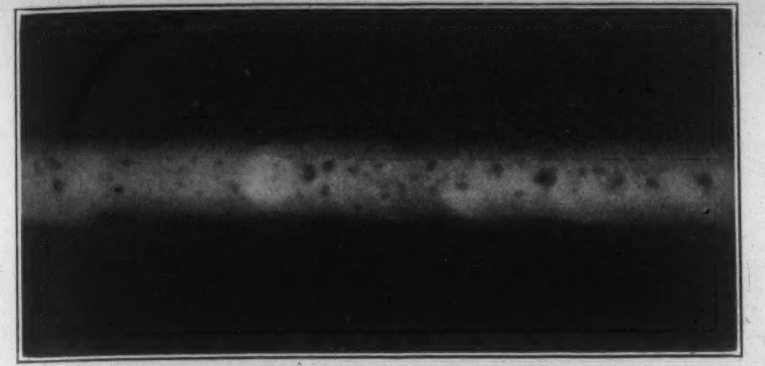


Figure 6—Radiograph of Weld Showing Imperfections

3. **Automotive and Aircraft Parts.** It may be truthfully stated that the remarkable dependability of automobile and aircraft motors in races and endurance flights such as those of recent months may be ascribed primarily to the assurance of soundness promoted by radiographic testing. This is particularly true for propellers in which soundness is absolutely necessary. Not only internal defects but also *surface* cracks which have escaped attention are immediately detected. Pistons have been surprisingly prone to disclose serious though unsuspected defects. All parts of an airplane may be inspected with X-rays from the cast cylinders to the spark plugs and the wooden framework. And where the safety of life is so utterly dependent upon sound mechanism and faithful performance it would seem little short of criminal not to use this positive method of specification and selection.

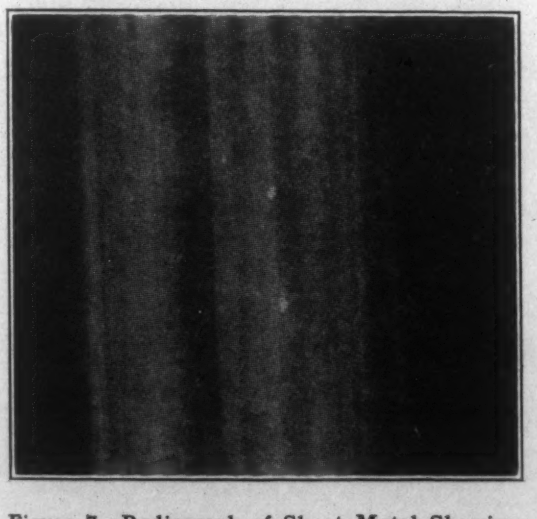


Figure 7—Radiograph of Sheet Metal Showing Slag Fibered with Metal by Rolling Process

4. **Rolled and Drawn Metal.** Figure 7 is the radiograph of a rolled sheet of steel containing slag inclusions which have been fibered with the metal in the rolling process. The very poor quality of such a sheet is clearly demonstrated by entire failure in forming operations. Figure 8 shows how an aluminum rod is affected by extreme cold drawing. The structure is such as to render the specimen worthless.

5. **Miscellaneous Applications of Metal Radiography.** Among a large number may be mentioned the inspection of insulated wires and cables and coated metals for breaks, of metal tubes and capillaries for clogging, of intricate assembled objects for proper adjustment of parts, of projectiles for proper location of caps and fuses as well as for complete filling by explosive, of gun barrels for rifling and defects, of molten metals inside of furnaces for melting point and surface tension, of ball bearings for soundness, of electric insulators for the presence of metallic particles, of metal radio transmission tubes for proper positions of grid and filament, of metal coins suspected of being counterfeit (by comparison of absorbing power for X-rays with that of an authentic coin), and of metal ores for gross constitution.

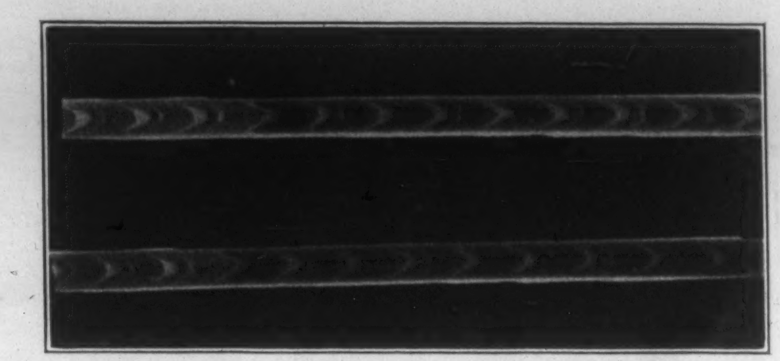


Figure 8—Radiograph of Cold Overdrawn Aluminum Rods

One of the great contributions of X-ray science, therefore, consists in the fact that the metallurgist may now examine the inside of an opaque object and determine its gross structure and diagnose the ills of metals just as the roentgenologist diagnoses the ills of the human body. But the possibilities of service of X-rays to the metallurgist are still far from exhausted. He may also determine the *ultimate fine structure* down to the atoms of metals and alloys, with all the fundamental information and rational explanation of properties which this affords. This phase of the science, the diffraction of X-rays by crystalline matter, will be the subject of the following sections of this paper.

Analysis of Steel for Manganous Oxide

Whenever steel is deoxidized with manganese, or manganese-bearing alloys, a certain amount of manganous oxide is formed and may remain in the steel as a complex inclusion with ferrous oxide, silicon dioxide or sulphides, or in the uncombined condition. Investigation of this phase of the deoxidation problem is, however, greatly retarded by the lack of a suitable analytical method for inclusions whose chief constituent is manganous oxide. These are characterized by their extreme solubility in acids, however dilute. Hence the Dickenson method, useful in analysis for inclusions which are mainly silica, where the steel is removed by solution in acids, is out of the question.

Experimentation at the Pittsburgh Experiment Station of the United States Bureau of Mines, Department of Commerce, in cooperation with the Carnegie Institute of Technology and the Metallurgical Advisory Board, has shown that electrolysis may be substituted for the acid solution process with considerable saving in time and with good recovery of the manganous oxide present in the steel sample. In the method in its present stage of development the sample is used as the anode in an electrolyte of ferrous sulphate. By the passage of current through the solution the iron is "plated" out on the cathode and the inclusions fall to the bottom of the container as a slime. It is essential that the iron plate out in a solid adhering layer to avoid contamination of the residue by metallic iron and that oxidation of ferrous salts in the solution be prevented.

One advantage of the electrolytic procedure is its relatively greater speed as compared with the Dickenson method. It is quite possible that it can be so adapted as practically to supplant the slower procedure for all types of inclusions.

Department of Commerce

A New Method of Testing the Depth of Case on Carburized Steel

By F. A. Firestone[1] and E. J. Abbott[2]

THE customary method of determining the depth of the case on carburized steel surfaces is to take several sample pieces from each batch, break them, and inspect the broken edges. This procedure gives exact assurance of the depth of the case on the samples, but, unfortunately, the test pieces are not much good after the test, and the condition of the remaining pieces in the batch is still open to question.

The present article describes an apparatus which was devised by the authors in the laboratories of the Department of Engineering Research of the University of Michigan for the Timken Roller Bearing Company. This apparatus to date has not been developed beyond an experimental form, but it offers considerable possibilities for control and testing work on case-carburized products.

Principle of Apparatus

The new apparatus for testing the depth of case depends upon the fact that the magnetic permeability of steel decreases with increase in carbon content. A diagram of the essential electrical circuit is shown in Figure 1. A step-down transformer is used on a 110-volt, 60-cycle line to supply current at a potential of 10 volts to the testing unit. This unit consists of a standard piece of the type to be tested, and a test piece, each of which serves as the core of a small transformer. The authors worked with roller bearing cups and cones but articles of other shapes, for example, piston pins, could be tested just as readily. The current derived from the step-down transformer passes through identical primary coils wound on each of the two pieces. The respective secondary coils, also identical, are connected in opposition to each other, and lead to a vacuum tube amplifier, the output of which is registered on a milliammeter graduated directly in units of case thickness.

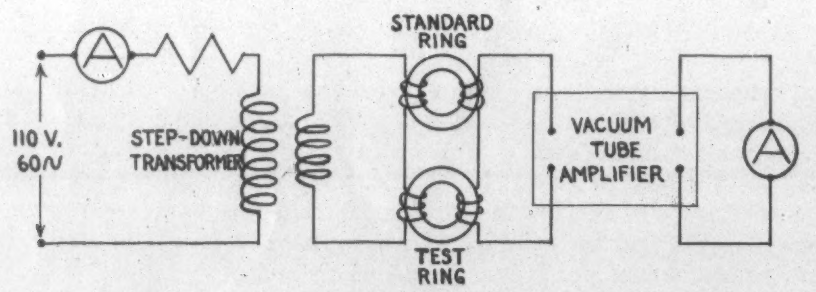


Figure 1

If the two pieces in the apparatus have the same permeability, the opposed secondaries exactly balance each other, no current flows to the amplifier, and consequently the meter reading is zero. If, however, the permeabilities of the pieces are not the same, the balance between the opposed secondaries is destroyed, and the small current flowing in this circuit is amplified to give a reading on the meter.

Method of Operation

In actual testing, the standard was an uncarburized piece. The meter was calibrated directly by testing carburized and hardened bearing cups in the apparatus, recording the deflection of the meter, and then breaking the test pieces and determining the depth of the case by actual measurement.

The mechanical details of the apparatus were developed with an eye toward possible utilization in manufacturing control work. To this end, the coils for the test ring were built in two pancake sections. One of these was fixed, and the other was hinged to close down and make contacts by operation of a foot lever. The necessary operations for a test were only three in number; (1) place test ring in fixed half of coils; (2) depress foot pedal, moving upper half of coil down over test ring, and automatically making contacts; (3) read deflection on meter.

Errors in Measurement

The actual quantity measured is the difference in magnetic permeability of a standard ring and a sample ring being tested. Any factor which affects the magnetic permeability will therefore influence the reading of the meter and may lead to erroneous conclusions. The factors besides case depth which were found to have the greatest influence on the magnetic permeability of the bearing rings were the composition of the steel and its heat treatment. It was necessary to closely control both composition and manufacturing operations in order to obtain trustworthy results. Close control is, however, quite customary in the manufacture of articles which are to be case-hardened, so that this method of testing has real practical significance.

---

[1] Assistant Professor of Physics, University of Michigan.

[2] Assistant Investigator, Department of Engineering Research, University of Michigan.

Slag Suitable for Making Ferromanganese Made in Electric-Furnace Tests

Approximately 150,000 tons of metallic manganese is being supplied annually to the steel industry in the form of manganiferous iron ores from the Lake Superior district. The North Central Experiment Station of the United States Bureau of Mines, Department of Commerce, in cooperation with the University of Minnesota has been developing modifications of blast-furnace and open-hearth practice so as to recover some portion of this large tonnage of metallic manganese in a form suitable for making ferromanganese, the alloy essential to the steel industry.

Electric-furnace tests were recently made at the Pittsburgh station of the Bureau of Mines to determine the relative merits of the electric furnace as compared with the open hearth for treating high-phosphorous spiegel so as to produce a high-manganese slag that can be used for making ferromanganese. These tests indicate that the electric furnace has the advantage of shorter time, more positive control of phosphorus and iron in the slag, more uniform slag lower in silica, and cleaner separation of slag and metal.

Department of Commerce

Correlated Abstracts

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts reviewing the work recently reported pertaining to certain subjects. These reviews will take into consideration the work of a number of workers. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

So-called "Accelerated" Endurance Testing of Metals, with a Review of Ikeda's Method

In determining the endurance limit of a metal, i. e., the stress it will withstand, repeated indefinitely, without breaking, it is necessary to run several specimens at stresses at which they will break and at least one at a stress at which it will remain unbroken for at least 10 million cycles for steel, and no one knows how long for non-ferrous alloys. Some experimenters are satisfied to stop at 50 million, and the patience of the majority gives out at 100 or 200 million.

The more common types of endurance testing or fatigue testing machines (the two terms are practically synonomous) run at 1500 to 2000 cycles per minute, i. e., they take about 4 days for a 10 million cycle run or over a month for one of 100 million. Routine testing, or quantity production of research data, therefore requires large batteries of machines, and the machines are relatively expensive.

The engineer realizes that resistance to repeated stress is the property most needed in many services to which metals are put. Data on fatigue *must* be obtained if engineering design is to be on a sound basis. As long as time-consuming methods have to be used the ratio of fatigue testing machines to tensile testing machines will remain low and accumulation of data will remain slow. Search for more rapid methods of testing therefore goes on.

The idea that testing different materials at one single high value of repeated stress which will break the specimen quickly and seeing how long it takes to break each one, gives a comparison of the service behavior under working stresses, is thoroughly abandoned by all who are experienced in fatigue testing. The Research Committee on Fatigue of Metals of the American Society for Testing Materials in its June, 1929, report has again emphasized this fact, for the benefit of those not versed in fatigue testing, in stating that the method is "utterly unreliable."

There are several possible methods of attack beyond the expensive one of putting in a large battery of machines. If very much higher speeds, many more cycles per hour, could be employed, that might be a solution.

Jenkin[1] devised a high speed machine, and a German (Hahneman-Hecht) high speed machine (500 cycles per second) is on the market.[2] In most high speed machines other than the air-driven type mentioned below, the accurate determination of stress is a real problem and they do not seem to have made much headway or to have met the situation.

At the Bureau of Standards in this country and the National Physical Laboratory in England work, as yet unpublished, is in progress, along the line of forcing a specimen to take up its own natural period of vibration under the impulse of jets of air. This method seems to allow measurement of the true stresses, but an unexpected difficulty common to all the high speed methods presents itself. Although at low frequencies up to, say, 5000 cycles per min. there is no detectable "speed effect" and endurance limits determined at, say, 2000 cycles and at, say, 5 cycles agree, yet when one uses the exceedingly high frequencies needed to speed up testing enough to relieve the situation materially, there is a "speed effect" and the endurance limit may be either above or below that found at the normal frequencies met in service, depending both on the speed and the material.[3] Hence, until the speed factors are known for each material the results cannot be used directly. Although a study of the speed factor will surely lead to a better understanding of fatigue phenomena, these super-high-speed methods do not as yet solve the immediate problem.

The question then arises, is there no property of a metal which can be quickly measured that correlates exactly with the endurance properties and thus may be used as an indirect measure of fatigue-resistance?

Metallographic or X-ray spectrographic methods have not so far shown promise of telling when fatigue failure starts, so we have to look to mechanical tests.

McIntosh and Cockrell[4] hint that electromotive force measurements of specimens in the course of an endurance test might lead to an accelerated test, but nothing has been heard of such a method since the suggestion in 1925.

There is no direct relationship between the static elastic limit and the endurance limit, but in steel, there is a broad generalization that the endurance limit for completely reversed stress is pretty nearly directly proportional to the tensile strength or the Brinell hardness, being roughly half the tensile strength. However, this is true only when the metal is free from internal stress and at hardnesses not much above 400 Brinell. The endurance limit, instead of being closely 50% of the tensile strength, may vary from 40% or somewhat less, to perhaps 60%. The inherent capability of a commercially perfect steel to resist repeated stress is probably in the neighborhood of, say, 55 to 65% of the tensile strength. Inclusions, tiny cracks, intercrystalline shrinkage giving a "loose" or porous structure, or any other internal flaw that acts to raise the local stress bring the actual endurance limit down. Hence approximations based on tensile strength or hardness may either lead to unsafe design or to use of an unnecessarily large factor of safety and consequent excessive weight. They would tell nothing about the danger from fatigue failure of "dirty" steel.

Worst of all, when one goes outside the realm of wrought ferrous metals, there is no correlation with strength or hardness. With some knowledge of the endurance limit and tensile strength of similar alloys one may make a reasonable guess as to the loads to use in endurance testing of a new alloy and thus cut down the number of specimens that must be broken before the endurance limit is found, but this is a guess only. Hence a still more direct correlation is sought.

On the hypothesis that break-down in fatigue seems to involve some plastic deformation on a very minute scale with consequent slip in the crystals, while up to the endurance limit deformation must be chiefly elastic, methods for the determination of what might be called a dynamic elastic limit were sought. Very delicate measuring devices were brought out for the study of the change in rate of deflection under variation of loading of a rotating beam. Some of these, with measurement by optical methods, were for a time hailed as a solution of the problem, and, for a limited range of steels, gave values corresponding pretty well with the endurance limits. But they fell down badly when applied to material that had been damaged by overstressing but not yet broken. Gough[5] found the same knee in the stress, cyclic-deflection curve of a badly damaged copper specimen as of an undamaged one. The National Physical Laboratory[6] states that the change in rate of deflection method is not reliable for high tensile steel such as spring steel. This type of method has reluctantly been discarded by its earlier proponents.

---

[1] C. F. Jenkin, "High Frequency Fatigue Tests," *Proc. Roy. Soc.*, **100A**, 119 (1925).

[2] Anon., "Electromagnetic Alternating Stress Testing Machine," *Engineering*, **122**, 723 (1926), see ref. 3.

[3] Compare J. Geller, "Die Eignung dynamischer Werkstoff-prüfmaschinen für die Untersuchung bildsamer Verformungen," *Archiv f. Einsenhuttenwesen*, **2**, 257 (1928).

[4] F. F. McIntosh and W. L. Cockrell, "The Effect of Phosphorus on the Resistance of Low Carbon Steels to Repeated Alternating Stresses," Carnegie Inst. Tech. Min. & Met. Invest., *Bull.* **25**, 1925.

[5] H. J. Gough, "Elastic Limits of Copper under Cyclic Stress Variations," *Engineering (London)*, **114**, 291 (1922).

The same situation is found in the case of "rise-of-temperature" tests, once thought to be useful, but soon proven inapplicable to hard steels. Indeed, Monel metal and some steels, at stresses below the endurance limit, will heat up so much in an endurance test as to be warm to the touch, to say nothing of showing a marked rise in temperature by the very sensitive thermocouple and galvanometer set-up used in the method, yet they will cool off and go on running as long as one cares to keep them running, without breaking. With the advent of more knowledge on the strengthening effect of understressing, it became evident that plastic deformation on a micro-scale, accompanied by change in rate of deflection or rise of temperature, does not necessarily connote damage that will result in failure. Conversely such methods do not necessarily detect damaged material or material with micro-flaws that serve as nuclei for fatigue failures and will ultimately lead to failure at a stress below that at which change in rate of deflection or rise of temperature becomes apparent. Mailander[7] points out that the deleterious effect of poor surface finish, or of non-metallic inclusions, is not brought out by accelerated methods, while it is shown by the old-fashioned test.

Another rather similar method of attack lies in the use of an inertia type of machine so designed that, once a specimen starts to fail, the load automatically increases, so that failure promptly ensues, due to the increased stress, within a smaller number of cycles than in the ordinary method of test. McAdam's reversed torsion machine[8] works on this principle. However, it would seem that such a method might fail in the case of an alloy like Monel, since the internal changes that give the "heat bursts" would presumably cause an increase in load in the inertia type. Moreover this type of machine has to be operated under the most refined speed control since the load increases as the square of the speed. At any rate, in his later work McAdam has chiefly relied on the old-fashioned method of testing many bars and getting a real endurance curve rather than to use this accelerated method.

The scheme of using one bar only, starting at a low stress and, if the bar does not break after a certain number of cycles, raising the stress, applying more cycles of stress and so on till it does break, is definitely discarded for precise work because of the phenomenon of "strengthening by understressing" which improves the endurance properties of the material. It gives a figure that is both untrue and unsafe if it be assumed that the virgin specimen would have stood the same stress without fracture that the "strengthened" specimen did. As a method of corroborating the fact that very many more cycles could have been withstood by the virgin material at the lowest stress, the one at which the test was started, this scheme is a great time-saver.

Lehr[9] says that in using the high speed Hahneman-Hecht machine, raising the stress from time to time on the same bar, about 70% of the results agree with ordinary fatigue tests, and 30% show high values.

Both Gough[10] and Moore and Kommers[11] discuss all these and many other suggested "accelerated" tests in their books and do not hold out much hope for widespread applicability of any of them.

Bohnszewicz and Späth[12] attack the problem in a different manner. They utilize a torsion machine which can be adjusted to give a desired static torsional couple on the specimen, the load being read by an optical lever system. Then they superimposed upon the static load an alternating torsional stress of definite magnitude.

The dynamic load is also measured optically. After allowing the dynamic load to act for the chosen number of cycles, the dynamic load is taken off but the static load kept on, and the static optical lever system read to see if the dynamic loading has caused the specimen to yield.

For every static loading there is a range of dynamic loading at which the specimen will begin to yield. By plotting and extrapolation to zero static load an approximation to the ordinary endurance limit figure may be obtained. But since the ordinary endurance limits for the lots of cast iron, Cr-Ni steel, cold worked and annealed open hearth steel and duralumin used are not given, no comparison can be made. The method seems to involve, as so many other accelerated methods do, danger of affecting the properties of the specimen through understressing. Mailander, in discussion, comments that the data presented for annealed open hearth steel give a yield under dynamic loading higher than the proportional limit in static test.

This is, of course, a more refined method for applying the old Smith[13] dynamic yield range scheme and has the advantage that the inertia type testing machine used by Smith, with its difficulty in speed regulation, is ~~not~~ required.

Hoyt, Moore and Gough[14] all give comparisons of the yield range by the Smith method with true endurance limits and Gough says the "results are reasonably consistent with the endurance limits for sound ferrous materials."

It is possible that the better apparatus of Bohnszewicz and Späth may lead to a closer relationship, but all such methods seem to tend to give unsafe values, both because of strengthening by understressing and because the damaging effect of inclusions acting as internal notches may not become detectable in the short period of an accelerated test at a given stress, though it would ultimately cause fracture in a non-accelerated test.

As Bohnszewicz and Spath themselves admit, fatigue failure is, in actual alloys which are not perfectly homogeneous or free from "stress-raisers," a *local* phenomenon. The various "accelerated" methods that depend on showing up an increased absorption of energy, such as the rise of temperature or change in rate of deflection methods, will show when energy is absorbed by the specimen as a whole, but so far fail to detect when only one spot, the nucleus for fatigue failure, begins to absorb it.

More recent lines of attack have been based on the idea that the beginning of a fatigue failure is a tiny crack, submicroscopic at first, and methods were sought which would indicate the extraordinarily tiny decrease in effective cross-section of the specimen due to such an incipient crack. Magnetic and electrical methods were applied. Fischer[15] attached the problem by magnetic methods. Induction was determined after various numbers of cycles of given stress, applied in a rotary beam testing machine. For some steels the curves of change in induction vs. cycles became horizontal at approximately the endurance limit but for others this was not the case until stresses far above the endurance limit were reached. There was no indication that the magnetic test could in any way be used to detect approaching failure. The magnetic changes observed as a result of repeated stress appeared to be due to relief of internal stresses, and these changes, which profoundly affect magnetic measurements, entirely overshadow any smaller changes due to the progress of a fatigue failure.

Another recent effort to find an accelerated method has been made by Ikeda,[16] in the research laboratories of the Japanese Government Railways. Ikeda attempts to correlate changes in electrical resistance, after the application of repeated stress, with the endurance limit.

That refined measurements of electrical resistance may reveal discontinuities in metal is indicated by the work of Sperry[17] whose "detector" measures indirectly, through vacuum tube amplification, local variations in resistance due to transverse fissures which occupy about 1 or 2% of the cross section of a railway rail, though it does not detect still tinier cracks.

---

[6] G. A. Hankins, "Discussion," *Jour. Iron and Steel Inst.*, **114**, 294 (1926).

[7] R. Mailander, "Discussion of Lehr, E. Oberflachenempfindlichkeit und innere Arbeitsanfnahme der Werkstoffe bei Schwingungsbeanspruchung," *Zeit. für Metallkunde*, **20**, 87 (1928).

[8] D. J. McAdam, Jr., "Accelerated Fatigue Tests and Some Endurance Properties of Metals," *Proc. A. S. T. M.*, **24** (2), 454 (1924).

[9] See ref. 7.

[10] H. J. Gough, "The Fatigue of Metals," London, **1924**.

[11] H. F. Moore and J. B. Kommers, "The Fatigue of Metals," **1927**.

[12] O. Bohnszewicz and W. Späth, "Die Schnellbestimmung der Dauerwechselfestigkeit," *Archiv. für. Eisenhuttenwesen*, **2**, 249 (1928). See also review, *The Metallurgist*, Dec., **1928**, 187.

[13] J. H. Smith, "Some Experiments on Fatigue of Metals," *Jour. Iron and Steel Inst.*, **82**, 246 (1910). See also **91**, 1915, p. 365.

[14] S. L. Hoyt, "Metallography, Pt. I. Principles—1920," p. 232. Moore, see ref. 11, p. 189. Gough, see ref. 10, p. 219.

[15] M. F. Fischer, "Note on the Effect of Repeated Stresses on the Magnetic Properties of Steel," *Bureau of Standards Journal of Research*, **1**, 721 (1928), *Res. Paper*, No. **26**.

[16] S. Ikeda, "A Rapid Method of Determining Endurance Limit by Means of Measuring Electrical Resistance," *Journal* (*Japanese*) *Soc. of Mech. Eng.*, **31**, 447 (1928). (In English.)

Abstract—"Electrical Resistance Method Determines Endurance of Metals, Automotive Industries," **60**, 476 (1929).

[17] E. A. Sperry "Devises Electrical Methods Made to Detect Flaws in Rails," *Iron Trade Review*, **83**, 1244 (1928).

C. W. Gennet, "Rail Detector Tests 2000 Miles of Track," *Iron Age*, **123**, 681 (1929).

Ikeda's work, sponsored by Professor K. Honda who has described the method in lectures given in this country this spring, therefore deserves more than passing consideration.

Ikeda uses Ono's rotary beam testing machine, which is similar in principle to the well-known R. R. Moore machine. Even his regular specimen without flanges is not free from criticism on the basis of too small a fillet, and it is obvious that the specimen he uses for accelerated testing would not be suitable for regular fatigue testing, since, in order to lead in the current to the rotating specimen, he provides two flanges which dip into a mercury trough. These flanges must lead to severe local stresses at their junction with the specimen and it is a big question whether any observed change is not due to the effect of these unknown local stresse rather than to the applied stress which is measured. The specimen is held in hard rubber chucks so as to be electrically insulated from the testing machine.

Ikeda's method consists in starting the specimen rotating at zero stress, measuring the resistivity, and after a certain number of cycles (3000 to 50,000), while the specimen is rotating, then loading the specimen by putting a weight on the loading device. After the chosen number of cycles at that first stress another resistivity measurement is made, the load is increased, and so on. Plotting the value for stress against resistivity (with suitable corrections if the room temperature changes) gives a break in the curve which is alleged to show the endurance limit. Such a method, instead of showing the properties of virgin material, necessarily involves "strengthening by understressing" and does not conform to the usual requirements for an acceptable test method. Of course, if it could be shown that the method, whether theoretically correct or not, did in every case correlate exactly with the endurance limit as determined by the usual method, it would not matter how violently it ran counter to accepted theory. But the evidence of correlation is none too good.

In the first place, the initial resistivity of different specimens of the same steel, assuming that they are all machined to the dimensions specified for the test specimen (and it is not stated that they varied), do not always agree well. Five specimens of one 0.69% C steel varied from 2.83 to 3.08 ohms in initial resistance. The alleged endurance limit, taken from the breaks in the curves, did not always check well on duplicate specimens. On 0.41% C steel values from 15,700 to 20,500 lbs./sq. in. were obtained.

The only true endurance limit testing, by accepted methods, that Ikeda records was to run one specimen of each steel at about 1500 lbs./sq. in. less than the alleged endurance limit for 10 to 30 million cycles without breaking, and to run one specimen of one steel at about 3000 lbs./sq. in. above the alleged endurance limit, the specimen breaking in about $6^{1}/_{2}$ million cycles.

Beside two screw stock steels, the only materials tested were five steels, of 0.11, 0.22, 0.41, 0.69 and 0.88% C, all in the annealed condition, furnace cooled from 900° C. The hardest steel tested had a Brinell number of 206. No heat-treated or cold-worked steel, and no non-ferrous materials were tested. In the 0.11% C steel the first break in the plotted curves is very slight and the marked knee of the curve comes at about twice the stress Ikeda chooses as the endurance limit. In one of the screw stocks (0.08% C, 0.13% P, 0.13% S) the first break is even less well defined, while in the other (0.13% C, 0.11% P, 0.10% S) the curve becomes very erratic and jagged after the first break. As no true endurance limits are given for the screw stocks one is at sea in attempting to correlate the results.

Inasmuch as other accelerated methods, such as the rise of temperature method and the change in rate of deflection method also, at first sight, appeared to show the endurance limits on soft steels but were found to be entirely useless on hard steels or non-ferrous alloys, one has to be very optimistic to hope that the Ikeda method will survive as a satisfactory accelerated test. Certainly until the method is proved, by comparison with real endurance limits obtained in the old-fashioned way, and over a much wider range of materials, it would be unjustifiable to assume that Ikeda's method tells the truth.

Tuckerman[18] sums this up well. He says "All of these short-time or accelerated methods need and must have, before we can rely on them, the confirmation of the old-fashioned endurance run to failure, carried to as many alternations of stress as is necessary to meet the practical conditions."

In his lectures in this country, Professor Honda also referred to an unpublished method under study in his laboratory by which magnetic testing of specimens at various stages in an endurance test is being studied as an accelerated method. The observations described appear to corroborate Fischer's findings and at least until the method is published, so it can be studied in detail, the odds seem against any wide usefulness of the method.

There may be a germ of usefulness in Ikeda's resistance method. If it were possible, by measuring the electrical resistance of different specimens, each run at one and only one stress, to determine after a few thousand cycles whether the specimen would or would not break if the run were continued, instead of actually continuing it, time would be saved. Whether the time saving would compensate for the extra cost of preparing the special specimen is another question.

Fortunately the resistance method is under study in the laboratory of Professor H. F. Moore at the University of Illinois and real facts as to the possibilities of the method, when properly applied, should soon be available. Till then, the situation remains the same; no accelerated fatigue testing method has yet been proved to be trustworthy. —H. W. GILLETT

Have Heat-Treated Aluminum Alloys a True Endurance Limit?

There has been much discussion among workers in fatigue of metals as to whether non-ferrous alloys, especially aluminum alloys, have definite endurance limits such as are well established for ferrous metals. Recent papers by Russian investigators[1] and by the Wright Field laboratory[2] deal with the subject, and reach rather contradictory conclusions. The Russian work being less readily available to American readers will be abstracted in some detail.

Nekrity and Bokov were moved by the discussion on the subject among American workers on fatigue of metals to study the question whether light aluminum castings used in the aircraft industry have an endurance limit or not.

No. 12 alloys in the annealed and the heat-treated condition were chosen for the study. Two melts were made, containing 7.87 percent Cu, 0.28 percent Fe, 0.35 percent Si and 8.06 percent Cu, 0.82 percent Fe, 0.46 percent Si. The melts were made from commercially pure aluminum and a 50/50 copper-aluminum hardener, heated to 700° C., held in the furnace for only a short time, then held in the crucible to cool before pouring. $ZnCl_2$ flux was used. The pouring temperature is not stated.

The castings were made in green sand, skin dried. The dimensions of the specimens are not given but a photograph indicates that most of the smaller specimens were machined from cast-to-size tensile specimens, poured upright, with a riser the diameter of the test-bar grip and as long as the test bar itself.

The specimens were either annealed at 400° C. for one hour and furnace cooled at the rate of about 50° C. per hour, or heated in a lead bath at 500° C. for one hour, quenched in hot water and aged 2 to 4 hours in an oil bath at 200° C.

Metallographic examination showed the usual structures for castings of this composition so treated. The static properties were:

	400° Ann.	500–200° Heat-treated
Tensile strength, lbs /sq in. ($^{1}/_{2}''$ (1 cm.) diam. bar)	16,800	24,000
Elongation, % in 2" (5 cm.)	2.1	0.6
Brinell hardness no. (10 mm. ball) 500 kg. load—30 sec.	50	116
Charpy-type impact strength—round drilled notch 4 mm. diam. on 3 x 3 cm. bar—breaking section 3 x $1^{1}/_{2}$ cm., kg. m.	2.37	2.09
on 3 × $1^{1}/_{2}$ cm. bar, breaking section $1^{1}/_{2}$ × $1^{1}/_{2}$ cm. kg. m.	1.25	1.08
Cantilever bend test, stress at first crack, 8 mm. diam. bar 75 mm. test length, lbs./sq. in.	19,500	34,000
Transverse test, stress at first crack 2 x 2 cm. bar, 20 cm. between supports, lbs./sq. in.	15,200	28,500
Compression test,		
Spec. 1 cm. diam., 1.2 cm. high		
Prop. limit, lbs./sq. in.	24,500	43,500
First crack, lbs./sq. in.	73,000	84,000

---

[18] L. B. Tuckerman, "Discussion," *Proc. A. S. T. M.*, **24** (2), 606 (1924).

[1] S. S. Nekrity and I. I. Bokov, "Fatigue Resistance of Castings of Light Aluminum Alloys Subjected to Repeatedly Reversed Stresses." (In Russian.) Vestnik inginieurov (Engineering), May and June, 1928. Nos. 5 and 6, pp. 235–251, 283–289. (Abstract made from translation by A. I. Krynitsky, Bureau of Standards.)

[2] J. B. Johnson, and T. T. Oberg, "Fatigue Resistance of Some Aluminum Alloys." Preprint No. 43 for *Proc. A. S. T. M.*, **29**, pt. II, 1929.

Dynamic tests were made, including a repeated impact compression or column test on grooved specimens, set vertically in a "free end" condition, the test section between the enlarged grips being 10 cm. long, 9 mm. diam. and notched at the middle to 7.5 mm. diam. by a 60° sharp groove. The impact was that of a 5 kg. weight falling 3 cm. The 400° annealed specimens stood only about 40 blows (30 to 75) while all the 500–200° heat-treated specimens were unbroken after 1000 blows.

On the other hand, when a repeated impact test on a Stanton-type specimen (but not in the Stanton machine) of a 13 mm. diameter bar notched down to 10 mm. by a 60° sharp groove, and struck over the groove, in the middle of a horizontal bar, length not stated, but apparently 10 cm. between supports, by a 5 kg. weight falling 2 cm. (the specimen being turned 180° between blows) the 400° annealed specimens stood 360 to 760 impacts, averaging 540, while the 500–200° heat-treated specimen stood only 104 to 140, averaging 125.

Repeated impact tests were also made on a Stanton machine this time using unnotched bars, 1/2 inch diam., and 5 inches between supports. The hammer weighed 2 kg. and was dropped distances ranging by 1 cm. steps from 1 to 9 cm.

The following results were obtained:

Height of fall, cm.	Number of Blows to Fracture	
	400° Ann.	500–200° Heat-treated
9	14	18
8	30	33
7	37	55
6	34	132
5	155	181
4	163	326
3	148	758
2	1158	23,119
1	13,084	100,000 not broken

Endurance tests were made on a cantilever type rotating bar at 900 r. p. m. using a machine of the Wöhler type.

The dimensions of the test bar are not given but a sketch shows that the bar is not tapered to give uniform load over a section of its length and the fillet between bar and grip appears of rather small radius. No statement is made as to whether the bars broke at the fillet.

On the 400° annealed lot of specimens a dozen bars were tested at fiber stresses ranging from ±16500 lbs./sq. in. to ±4450 lbs./sq. in. Only two bars lasted over a million cycles, one at ±4500 lbs./sq. in. breaking at about 3,500,000 cycles, while the one at ±4450 lbs./sq. in. was unbroken after more than 24,000,000 cycles.

On the 500–200° heat-treated lot, six specimens were broken at the stress first imposed. Four of these six, tested at stresses ranging from ±14,600 to ±11,850 lbs./sq. in., broke at one-third to two-thirds of a million cycles. The other two specimens, both tested at about ±9150 lbs./sq. in., broke at about 2,500,000 and 6,000,000 cycles.

At ±7800 lbs/sq. in., one bar was removed unbroken after 25,000,000 cycles and another, after running 34,500,000 cycles without fracture, was raised to ±11,800 lbs./sq. in. and broke after about 600,000 cycles, which lies practically on a curve drawn on the basis of bars broken at the original stresses. Another bar, run at about ±7200 lbs./sq. in., unbroken after about 11,500,000 cycles, was then raised to ±14,500 lbs./sq. in. and broke after about 375,000 cycles, which is a somewhat longer life than that shown for that stress from the curve for bars broken at the original stresses. This indicates strengthening by understressing. Two other bars understressed at still lower stresses and then run at higher stresses also showed strengthening. Nekrity and Bokov do not comment on the strengthening by understressing and their data have to be replotted to bring it out.

The data are given in Table 1 so the interested reader may plot it for himself.

From these few data Nekrity and Bokov deduce that the specimens have real endurance limits and fix the "safe stresses" at ±4150 lbs./sq. in. for the 400° annealed material and ±7700 lbs./sq. in. for the 500–200° heat-treated material. Instead of plotting on logarithmic or semi-log coordinates they plot stress vs. the reciprocal of the number of cycles and in a table they give the reciprocal value without any attention to whether or not the bar broke at that stress or remained unbroken, or whether or not the bar had previously been run at a lower stress.

When the data are plotted on the usual semi-log coordinates the breaks in the curves do not appear anywhere near as marked as they do by the authors' method of plotting and the conclusion that there is a definite endurance limit, drawn on the basis of so few tests, extending only to 25,000,000 or 35,000,000 cycles, on non-ferrous material like the alloy in question seems a bit sweeping, although the understressing data on the heat-treated alloy appear to substantiate the conclusion.

Table 1

Stress Kg./mm.^{2}	Lbs./sq. in.	Life-cycles
No. 12 ALLOY ANNEALED AT 400° C.		
11.70	16,500	277
10.85	15,500	1145
9.81	14,000	14,330
8.21	11,700	51,871
8.07	11,500	33,684
6.85	9750	118,980
5.31	7550	86,258
4.62	6575	133,554
3.96	5650	297,299
3.88	5525	722,430
3.16	4500	3,317,344
3.12	4450	24,344,063 not broken
No. 12 ALLOY 500° C. HOT WATER QUENCHED—200° C.		
10.40	14,800	274,268
8.90	12,700	479,813
8.41	11,950	627,367
8.15	11,600	444,363
6.45	9175	2,634,573
6.42	9125	6,198,534
5.50	7825	24,821,300 not broken
5.07	7200	11,340,011 not broken, raised to
10.22	14,500	374,328 broke
3.25	4650	13,556,207 not broken, raised to
5.42	7700	34,421,300 not broken, raised to
8.28	11,800	639,112 broke
2.00	2850	14,966,120 not broken, raised to
5.70	8100	23,864,130 not broken, raised to
9.45	13,500	633,870 broke

Johnson and Oberg[2] find that in the study of fatigue of heat-treated duralumin, specimens which have run 500,000,000 cycles without fracture, when retested at a higher stress, show signs of breakdown, which started at the original stress and was accelerated at the higher stress, although after 100,000,000 cycles at the same stress no perceptible damage or improvement was noted on retesting at a higher stress. Such very slow development of damage, not apparent at 100,000,000 and taking 500,000,000 to bring it out, emphasizes the need for extremely long-continued tests if the question of the existence or non-existence of a true endurance limit for these aluminum alloys is to be established.

Moreover, if Nekrity and Bokov's data for heat-treated No. 12 alloy are plotted on Johnson and Oberg's diagram the resulting curve appears to belong to the same family as do Johnson and Oberg's, although its slope is not so steep. In two of Johnson and Oberg's curves single points showing longer lives than would be predicted from the curve occur at around 10,000,000 to 20,000,000 cycles, which would mislead an investigation into thinking he had signs of a true endurance limit if he did not make still longer runs at lower stresses.

It is of interest to note that Johnson and Oberg's data show that duralumin which contains about 1 percent more silicon than normal duralumin and which shows a higher static tensile strength and proportional limit, with only about half the elongation, and much increased hardness (142 Brinell vs. 117), nevertheless has lower fatigue resistance. This is slightly more marked at higher stresses. At ±20,000 lbs./sq. in. the low silicon, normal, duralumin has a life of about 30,000,000 cycles against about 15,000,000 for the high silicon duralumin, while at ±14,000 lbs./sq. in. the lives are, from the curves, low silicon normal duralumin about 700,000,000; high silicon, about 400,000,000.

In a private communication from Dr. Zay Jeffries, he states that while No. 12 alloy (8 percent Cu, not heat-treated) has a higher "500 million cycle endurance limit" (if the term may be used) than does the heat-treated "No. 195" alloy of 4.5 percent Cu, 0.8 percent Si, which has a "500 million cycle endurance limit" of only about ±6000 lbs./sq. in., yet at 100,000,000 cycles the No. 195 alloy is markedly superior. This superiority is not only shown in laboratory tests to 100,000,000 cycles, but also holds for conditions of service in which resistance to fatigue is commonly considered a requirement. In Dr. Jeffries' opinion, for many practical applications of this sort the determining factor

(*Continued on page 37*)

Abstracts of Current Metallurgical Literature

In this section, there will each month appear brief abstracts of articles in the metallurgical field appearing in various publications. These abstracts are not critical, but merely review developments as they are recorded. Every effort will be made to report on all articles as soon as possible. In the very near future the abstracts will be arranged according to subject.

Solubility of Carbon in Normal and Abnormal Steels. OSCAR E. HARDER AND WILLARD S. JOHNSON. *Transactions American Society for Steel Treating*, January, 1929, pages 49–68.

Continuation of study reported in *Transactions American Society for Steel Treating*, June, 1928, pages 961–1008. In the present investigation a study has been made of the solubility of carbon in typical normal and abnormal steels, making use of longer carburizing times and different carburizing temperatures. The carbon contents of the cases produced have been checked by chemical analyses. The method has been to quench from various temperatures, including the carburizing temperature and lower temperatures, usually by intervals of 50° F., and note the temperature at which the separation of the carbide first took place. The results show that for a given carbon content, precipitation takes place in the abnormal steel at a higher temperature. It was also found that, as the carburizing temperature increases, the amount of carbon taken up by the normal and abnormal steels becomes essentially the same. The results seem to be consistent with the previously proposed mechanism of the formation of the characteristic microstructure found in abnormal steels.

On the Stepped Lowering of the A_1 Transformation in Steels. TAKEJIRO MURAKAMI. *Tech. Repts. Tohoku Imp. Univ.*, **8**, 245–253 (1929).

Transformation in a pure substance is gradually lowered as rate of cooling is increased, but the A_1 transformation in steels is lowered in "steps" as the rate of cooling increases or the maximum heating temperature rises. Discusses some examples, showing results graphically.

Le Procede D'Elaboration de L'Acier et les Caractéristiques D'Endurance aux Efforts Alternes. R. CAZAUD. *Aciers Speciaux Metaux & Alliages*, January, 1929, pages 14–22.

Investigation of the behavior of two steels of the same composition, but produced, respectively, in the electric furnace and in the Bessemer converter. Both are chromium nickel steels.

Étude des Fours a Réchauffer, avec Réupérateurs, dans Lesquels on Détourne une Partie des Fumées Chauffants. *Génie civil*, January, 1929, pages 7–12.

Classification of types with considerable theory, and a few examples of furnaces for reheating blooms and billets.

Re-Heating Furnaces for Alloy Blooms; Triple Fired Recuperative Type. *Iron & Coal Trades Review*, Feb. 1, 1929, page 175.

Installation of Timken Steel & Tube Co., Canton, Ohio, for reheating high-quality blooms on quantity production basis. Includes two large continuous furnaces using natural gas as fuel and having capacity of 40 tons an hr. each. Abstract from *Iron Age*.

Factors in the Superiority of Forgings. JOSEPH R. MILLER. *Iron & Steel of Canada*, March, 1929, pages 89–90.

Forgings afford superior possibilities on account of flexibility of the process permitting control of inclusions and voids, welding and closing up of interspaces, avoidance of overstrain in working and production of grain refinement by control of heating and by working at correct temperatures.

Practical Applications of the Nitriding Process. H. W. MCQUAID. *American Machinist*, Mar. 7, 1929, pages 387–388.

Despite cost of process, it is applicable in certain cases where carburizing proves unsatisfactory, and where resistance to corrosion is important where toughness is required, steel should contain molybdenum, should be quenched and drawn, and subsequently nitrided with undissociated ammonia held above 70%.

Heat Treatment and Properties of Cast Iron. P. SCHOENMAKER. *Blast Furnace & Steel Plant*, February, 1929, pages 283–286.

In general the hardening and tempering process has but little effect on mechanical properties of cast-iron hardness but can be changed. This is because distribution of free carbon is not affected by the heat treatment; hardness, however, depends on the structure of the matrix and therefore on the hardening and tempering temperature.

Electric Melting of Alloy Steels. H. M. GERMAN. *Blast Furnace & Steel Plant*, February, 1929, pages 274–276.

Methods are still empirical; certain operations can be standardized, and furnace and laboratory equipment is being improved, but quality depends largely on skill of melter. Reviews development and reviews operations with various types of furnaces.

Physical Chemistry of Rimmed Steel. J. E. CARLIN. *Blast Furnace & Steel Plant*, February, 1929, pages 261–262.

Amount of carbon monoxide present in a steel before addition of manganese is dependent on temperature only, and is independent of carbon or ferrous oxide content. After addition of manganese, high-carbon steels contain less carbon monoxide than low-carbon steels. Evolution of carbon monoxide depends on actual solidification of the metal. Temperature and carbon content are the most important factors in the manufacture of rimmed steel.

New Facts about Manganese Steel. *Iron Age*, Feb. 28, 1929, pages 600–601.

Review of Howe memorial lecture by John Howe Hall. Photomicrographs show various structure exhibits "zebra" markings which appear most prominently in specimens containing free carbide. Tentatively, they are called "pearlitic threads" and they may be paths of carbon migration. This investigation controverts previous opinion that austenitic manganese steel cannot be changed into the other well-known transformation products by heat treatment.

Trends in Engineering Alloy Steels. *Iron Age*, Jan. 31, 1929, pages 333–334.

Lower carbon and higher alloy content produce high tensile strength of alloy steel combined with toughness and ductility of plain carbon steel of low carbon content. Low-carbon, 3% chromium steel exhibits valuable characteristics.

Further Observations on the Microstructure of Martensite. FRANCIS F. LUCAS. *Transactions American Society for Steel Treating*, February, 1929, pages 339–367.

Quenching and tempering experiments on commercial tool-steels of high quality. Many typical structures are shown. Tentative conclusions are: (1) A martensitic needle is a decomposition along octahedral crystallographic plans of austenite. (2) A martensitic needle is confined to an area of uniformly oriented austenite; that is, a needle never crosses a grain boundary or a twinning plane. (3) Martensitic needles darken with sodium picrate; they have a mottled, granular appearance. (4) A martensitic needle is an aggregate and not a solid solution; it indicates decomposition of austenite, probably to alpha iron and iron carbide in highly dispersed state.

Surface Cooling of Steels in Quenching. H. J. FRENCH, G. S. COOK AND T. E. HAMILL. *Transactions American Society of Steel Treating*, February, 1929, pages 217–288.

Experimental study on steel spheres, $^1/_4$–11$^1/_4$ in. in diameter, quenched in water, sodium hydroxide solutions and oils, and cooled in air. Results indicate desirability of adequate circulation of cooling medium for production of uniformly hardened steels. Adherent scale, rough surface and large amounts of dissolved gases in cooling medium tend to retard cooling and to promote unstable conditions, thus preventing uniform hardening. For wide cooling ranges (such as 1605 to 390° F.) cooling times increase with size more rapidly in water than in air or in 5% sodium hydroxide.

Effect of Furnace Atmospheres on Steel. R. G. GUTHRIE. *Transactions American Society of Steel Treating*, January, 1929, pages 96–116.

Includes discussion. Tests with atmospheres ordinarily encountered in heat-treating furnaces, employing temperature of 1500° F., as being an average for heat treatment of carbon steels of about the eutectoid composition. Scaling or oxidation with oxygen does not cause decarburization at this temperature. Carbon dioxide alone is not neutral and is both a decarburizer and oxidizer of iron and steel. Intelligent use of raw gas, independent of that consumed through the burners, offers possibilities of extremely flexible conditions of furnace atmospheres, and is, therefore, a valuable adjunct to the heat treatment of steel.

Sponge iron, a raw material for electric steel. N. K. G. Tholand. advance copy, American Electrochemical Society, May, 1929, meeting.

Commercial Swedish sponge iron can be produced containing about 90% metallic iron, 0.014% P, 0.025% S, 0.025% Mn, 0.03% C and free from Cu, Ni and metallic Si, the balance FeO, SiO_2 and a little V_2O_5. It is claimed that most of the S is present as CaS, and that some of the V is reduced in electric furnace or open hearth melting of the sponge. The 8 or 10% of FeO plus SiO_2 is said to flux out without producing dirty steel.

Claims for a wider hardening range (fine grained structure whether quenched from 770° or 890° C.) of steel made from this Hoeganaes sponge would indicate reduction of V with its attendant effect in producing fine grain, but no analyses of these steels are given for V, though data are given on wire made from the sponge which show 0.08% V. While several tables of data are given, indicating better physical properties for steel made from the sponge than for comparable commercial steels from other raw materials, the statements made are so sketchy that while the results might serve as sales arguments for this particular sponge iron, one is at a loss to decide whether sponge iron has any special virtue in itself or whether the vanadium is showing its effect. A more satisfactory comparison would be against steels to which vanadium had been added to produce the same composition. The opinion is quoted that "a more elastic cohesion between the iron crystals in sponge iron steels may have a definite bearing on the hot and cold working of the metal." Most of the arguments are about as hazy as this, but the author's conclusion is merely that the material ought to be tried on a large scale so as ultimately to give a sound basis for figuring the commercial value of different grades of sponge iron.

Change in microstructure of iron at A_3 transformation point. B. A. Rogers (Western Electric Company), American Institute of Mining and Metallurgical Engineers, *Tech. Pub.* No. **218**, June, 1929.

By use of a tiny furnace with a tungsten heating element and fused silica window, metallographic examination can be made of a metal specimen heated to 1100° C. or higher, in an atmosphere of hydrogen or nitrogen. The specimen is about 20 mm. from the microscope objective so that examination can be made at 100 diameters. Details of construction and a sketch of the furnace are given. Vacuum-fused electrolytic iron, examined at the A_3 point, shows a "wave" of change of structure as the transformation progresses. The wave was marked in a 45% Fe, 55% Co alloy. In pure Co markings appeared at 400° C. but not till 450° C. was there much change, when equilateral triangles, parallelograms and trapezoids appeared.

Structural steel showed no wave, although the appearance was different about and below the transformation range. Iron heated in nitrogen showed pits at the grain junctions some 30° C. below the normal A_3 on heating, the pit increasing as A_3 was approached. This indicates intergranular penetration by nitrogen with consequent lowering of the A_3 point at the affected localities.

The thermal and electrothermal reduction of zinc oxide, and remarks on the use of iron resistors up to 1200° C. O. Dony Henault, (University of Brussels, Belgium), advance copy, American Electrochemical Society, May, 1929, meeting.

A soft iron resistor of diameter over 5 mm. in a Co atmosphere served for laboratory studies such as those on the reduction velocity of zinc oxide. Work at 1000° C. and 11 atmospheres pressure indicated that quantitative reduction of ZnO could be obtained and it is considered that internal heating of the charge by electrothermal methods offers possibilities.

Method of making copper replicas of corroded metal objects. E. S. Taylerson (American Sheet and Tin Plate Company), preprint 39 for *Proceedings, American Society for Testing Materials,* **29**, Pt. 2 (1929).

Field measurement of corrosion is difficult when the object studied must go back in service or to a continuation of an exposure test. If the object is freed from corrosion products as by sand blasting, and electrotyping practice then applied, dusting with graphite, making a wax replica by casting melted wax, or, still better, molding it under pressure, then electroplating the wax, a copper replica is obtained.

Since this only applies when the corrosion products may be removed, and where the corrosion pits are not too deep nor undercut, and since only rather flat objects may readily be so treated this useful method unfortunately has but limited application.

Bearing bronzes with and without zinc. H. J. French and E. M. Staples (Bureau of Standards), *Research Paper* No. **68**, *Bureau of Standards Journal of Research* **3**, 1017 (1929), preprint 49 for *Proceedings, American Society for Testing Materials,* **29**, Pt. 2 (1929).

Nine bearing bronzes, ranging in tin content from 2 to 10% and in lead content from 2 to 30%, and nine in which 4% of the Cu was replaced by Zn, were studied by impact tests, repeated pounding tests, and wear tests, at room temperature, 175° and 315° C. The zinc had no notable effect on any property, notwithstanding the fact that many existing specifications limit zinc to so low a figure as to raise the cost of the bearings by limiting the amount of scrap that can be used without exceeding the zinc limit. It is stated that the conclusion that the effect of zinc is insignificant is not to be construed necessarily to apply when other impurities are present.

Of the straight Cu-Sn-Pb alloys, those with less than 4% Sn are considered unsuited for general bearing service. If high in lead they may serve for light loads but to give good resistance to deformation more Sn is required. With less than 5% Pb, alloys of 4 to 15% Sn should be used only where lubrication is sure to be maintained. With more than 11% Sn the notch toughness is too low.

The most generally useful group contains 4 to 11% Sn and 5 to 30% Pb. Above 8% Sn the notch toughness falls off but the resistance to deformation increases. Increase in Pb increases the resistance to wear in metal to metal contact. Increase in lead decreases resistance to deformation (load-carrying ability) but this decrease is less notable than is the increase due to increase in tin. Depending on the nature of the service, i. e., the load to be borne, the need for high impact strength and for insurance against wear when lubrication fails, the optimum Sn and Pb content will vary. Only at 8% tin, in resistance to impact, is there any sharp change in properties, so that hair-breadth chemical limits in specifications seem unwarranted. Such common alloys as 76 Cu, 10 Sn, 10 Pb, 4 Zn and 85 Cu, 5 Sn, 6 Pb, 4 Zn, intermediate compositions or similar compositions with higher Cu and without Zn show up by these physical tests as suited for many types of bearing service. Since these are known to be good bearing metals, the methods of evaluation appear sound. By these tests an alloy of 70 Cu, 12 Sn, 14 Pb, 4 Zn appears promising when high loads must be supported, when lubrication may fail, and when high impact strength is not required.

Metallization of the oxide of iron in ilmenite. R. J. Traill and W. R. McClelland (Canadian Department of Mines), advance copy, American Electrochemical Society May, 1929, meeting.

By heating in a rotary oil fired kiln, ilmenite plus coal or coke is reduced to sponge iron, the TiO_2 remaining unreduced. Gangue and excess coal or coke are removed by magnetic separation. The metallic iron, TiO_2 mixture is leached with $FeCl_3$, for electrolytic recovery of Fe, or by H_2SO_4 if the $FeSO_4$ is to be run to waste. This leaves a high TiO_2 concentrate. Between ore and concentrate the Fe fell from 39% to 6.3%, the TiO_2 rose from 31.8% to 75.9%.

Manufacture of Thick-Skinned Ingots of Rimming Steel. Henry D. Hibbard. *Fuels and Furnaces,* March, 1929, pages 395–397.

Deals with action of metal in the ingot and influence of speed in teeming.

Case Carburizing of Steel. H. B. Northrup. *Fuels and Furnaces,* March, 1929, pages 347–352.

Discusses development of process, theory of carburizing, constitution of carburizing compounds, case characteristics, composition of carburizing steels, and carburizing equipment.

Depth and Character of Case Induced by Mixtures of Ferro-Alloys with Carburizing Compounds. E. G. Mahin and R. C. Spencer. *Transactions, American Society of Steel Treating*, January, 1929, pages 117–144.

Includes discussion. Various elements occurring in steel affect rate of carbon absorption and carbon migration during surface carburization, and iron and steel may be "cemented" with various elements other than carbon. This investigation shows that if silicon absorption is confined to surface layers of iron or steel, carbon absorption may be retarded without materially affecting rate of inward migration of carbon. This principle permits production of deep case without zone of free cementite. Uses ordinary carburizer with ferrosilicon and, by using higher temperatures, shortens time for case carburization.

Heat Treating Furnace Design. J. H. Gumz. *Fuels and Furnaces*, March, 1929, pages 391–392.

Involves more than furnace itself. Problems to be considered are (1) whether the furnace is to be in line of production; (2) whether continuous or batch type; (3) number of hours of operations. Annealing, hardening and drawing furnaces should be so fired that flame does not come in contact with material being treated. Homogeneous and properly proportioned mixture of gas and air will burn with very short flame which may develop temperature approaching 3400° F. Direction of radiated heat is important, and uniformity of heat is one of the chief problems involved in design of salt baths. Excess or spot heating breaks down certain salt compounds and decreases life of pots. Muffle wall around baths may overcome difficulties. For discontinuous heating of small parts, furnace refractories may be light, perhaps 2–3 in. thick, but heavy insulation of best type is essential in furnaces operating for long periods.

Need More Accurate Determination of Working Fibre Stress. S. W. Miller. *Iron Trade Review*, Feb. 14, 1929, pages 464–466.

Factors of safety are not based on definite knowledge. Bend test, since it combines both elongation and reduction of area, should be better than pure elongation as a measure of ductility, and is the only reasonably accurate method. There is no theoretical basis for working fibre stress and any formula must be empirical. Formula should provide for lower working fiber stress where material has low ductility and working fiber stress should depend directly on tensile strength. Formula developed by A. B. Kinzel is $S = \frac{T}{7.15} \sqrt[3]{\frac{E}{10}}$, in which S = allowable working fiber stress, T = ultimate tensile strength, and percentage of elongation is determined by bend test.

Wrench Parts Hardened by Heat Treating. J. E. Hart. *Iron Trade Review*, Feb. 14, 1929, pages 461–463.

Plant of Walworth Co. After forging and trimming, and before machining, forgings are annealed, grain is partially refined, and pearlite and sorbite are changed to a partially globular pearlitic structure which is readily machined. Effectiveness of annealing is constantly checked by Brinell instrument by the sampling method.

Corrosion-Fatigue of Metals. *Metallurgist*, Jan. 25, 1929, pages 3–6; Mar. 26, 1929, pages 44–48.

Refers to 6 papers of D. J. McAdams, setting forth his work in this field. Characteristics of "corrosion fatigue" can be conveniently studied in 2 distinct stages. In the first stage, the effect of corrosion and fatigue operate simultaneously throughout each experiment. To such tests the term "corrosion fatigue" was exclusively applied. Extended experimentation on a wide range of both ferrous and non-ferrous metals indicate that with most of these metals the value of corrosion-fatigue limit is independent of heat treatment, and, in some alloys, largely independent of chemical composition. Dr. McAdams' later work aims at isolating and evaluating relative effects of the numerous factors (each a variable) operating during a standard corrosion-fatigue test. These variables include temperature, time, frequency of cycle, number of applied cycles and size of specimen. Method was to observe effect of one variable while maintaining the other factors constant.

Microstructure of Rapidly Cooled Steel. J. M. Robertson. *Iron Steel and Institute* (London) (advance copy), May, 1929, 29 pages.

Results presented constitute part of a research on intermediate rates of cooling and their relation to wire-drawing, which is being carried out for the Wire Ropes Committee of the Safety in Mines Research Board. By cooling small steel specimens in molten metal at various temperatures between 600° C. and 220° C., the sequence of structures obtained when austenite is caused to decompose at progressively lower temperatures has been investigated. The ultimate composition of the product of the decomposition of austenite appears to vary with reduction of the temperature at which the transition takes place. When the transition takes place at the normal temperature the product consists of α-iron and cementite. As the temperature of the transition is lowered, more carbon is retained in solution in α-iron, and less separates as cementite. The crystallographic form of the product of the decomposition of austenite depends on whether the decomposition of austenite is initiated by the allotropic change or by the formation of cementite. The Ar' change is initiated by cementite, and the series of structures obtained at Ar' is determined by this fact. The Ar'' transformation is initiated by the allotropic change, and the structures formed at this change point are related to the crystallographic planes of the austenite. The relations between the Ar' and Ar'' points are determined by the fact that the allotropic change and the formation of cementite are differently affected by variations in the rate of cooling. The formation of cementite is slightly lowered, interrupted and suppressed by a progressive increase in the rate of cooling. The allotropic change is progressively lowered as the rate of cooling is increased. The progressive lowering of the allotropic change cannot be realized in steels containing more than 0.2% of carbon, for in these steels, with certain rates of cooling, the decomposition of the austenite is initiated by the formation of cementite, and this change must be suppressed before the initiation of the transformation by the allotropic change can again be realized. In low-carbon steels, however, the structure passes directly from ferrite and pearlite to solid-solution structures, with crystallographic form similar to those produced when the Ar change in high-carbon steels takes place at a high temperature. There are two series of structures produced by increasing the rate of cooling. Within each series the variation in structure is gradual. All structures formed at Ar may be tempered, and the tempered structure is related to the original structure, to the time and to the heat of tempering. The structures formed by cooling at different rates cannot be obtained by tempering other structures. So far as crystallographic form or structure is concerned, there is no relation between cooling at different rates and tempering at different temperatures. The same ultimate constitution may, however, be produced in either of two ways. When the solid solution produced by very rapid cooling is reheated, carbon gradually separates from solution and forms cementite. By reheating to different temperatures, all variations in constitution between solid solution and ferrite-cementite aggregate may be obtained. Thus, the globular structure, formed by tempering above 600° C. may have the same ultimate constitution as the fan structure, but the crystallographic form and the general properties of these two structures are entirely different.

Stress-Strain Diagrams of a Heat Nickel-Chrome Steel. Andrew Robertson. *Metallurgist*, Feb. 22, 1929, pages 23–26; March 29, 1929, pages 35–36.

Tests of the strength of tubes. The following conclusions were reached. (1) The material is hardened by heating to 800 or 900° C. and cooling in air. It may be noted that in this condition the material is too hard to be tooled, and only grinding operations are possible. (2) The material is annealed—fully tempered—by heating to 650° C. and cooling in air. (3) If tempered in the region 700 to 750° C. and cooled in air, the material has a very low elastic limit, and the strains at comparatively low stresses are very considerable. (4) If the material is hardened from between 800 and 900° C. and subsequently tempered at 400° C., it possesses a very high elastic limit, 60 tons per inch, and is toolable. (5) If the material is heated to 700° C., and subsequently tempered, the elastic limits and yields are relatively low. (6) There is evidence of a definite "mass" effect, as the results by slow cooling are different from those obtained by simply allowing the specimens to cool in air. The slowly cooled material has a very sharp yield at 24 tons per in. If the slowly cooled material is heated at a temperature just within the critical range (675° C.) and air-cooled, the limit of proportionality and yield are both lowered considerably, but the latter is made less definite. These results correspond with those obtained in compression

New Method for the Production of Sound Steel. Sir Charles Parsons and H. M. Duncan. *Iron and Steel Institute* (London) (advance copy), May, 1929, 12 pages.

Method of ingot casting to overcome segregation and axial unsoundness. Process covered by British patent 278,032, comprising pouring of molten metal into mold with horizontal dimensions exceeding the vertical; thick refractory materials covering sides of mold, and a bottom chill (preferably of metal) of large dimensions; preheating of mold to a high temperature "of the order of molten steel" before pouring the metal therein; and continuously supplying heat to the upper surface of the molten metal after casting, so that upper region is last to solidify. Paper includes sulphur prints, graphs of mechanical properties, and many photomicrographs of a specimen ingot of circular horizontal cross-section 70 in. in diameter, 45 in. high and weighing $20^1/_2$ tons.

In the ordinary way, under a vertical press, this type of ingot 72 in. in diameter can be forged to a bloom 40 in. in diameter in a single heat. It is claimed that by this process, steel free from segregation and axial weakness can be produced at reasonable cost.

Electro-Deposition of Cadmium for Rust Prevention. S. WERNICK. *Metallurgist,* March 29, 1929, pages 36–37.

Widely divergent solutions are used, but one of the desiderata is uniformity in composition. Relatively high concentration of metal is desirable; 30 g. of cadmium per liter is satisfactory. Free cyanide may vary widely; about 100% over the combined cyanide content is best. Caustic alkali should amount to 15–30 g. per liter, the larger amount giving better results. Elevated temperature of solution is objectionable. Current density of 10–15 amp. per sq. ft. is best.

Fighting Rust. WILLIAM M. BARR. *Houghton's Black and White,* March, 1929, pages 3–5.

Brief, non-technical review of loss due to corrosion of metals in service and in storage coating for metal parts in storage should be impervious to air and moisture, must adhere closely, must be flexible, must be inert and easily removable, and must act as an inhibitor. Coatings with similar properties for metals in service, as on railroads, are more satisfactory than crude fuel-oil which lacks permanency.

Metallurgical Specifications for High-Class Cast Irons. HORACE J. YOUNG. *Metallurgist,* Feb. 22, 1929, pages 28–29.

Having obtained a test piece having the same strength, hardness, composition and structure as the casting itself it is not difficult to specify the tests it must pass. Carbon limit should vary for various kinds of casting; silicon should be lower (1–1.20%) in heavy than in light castings; maximum phosphorus and minimum manganese should be specified; sulphur is relatively unimportant. Discusses meaningless terms of specifications, but, in general, information is suggestive rather than specific.

Neuere Untersuchungen an Vergütbaren Al Legierungen. W. FRAENKEL AND L. MARX. *Zeitschrift für Metallkunde,* January, 1929, pages 2–6. Discussion.

Paper of the Deutsche Gesellschaft für Metallkunde, General Convention, Dortmund, June, 1928. By means of five Al-alloys constituted as simply as possible, a comparative examination of the occurrences at refining at room temperature, at 50, 100, and 150° C., and at this so-called boiling refinement is carried out by measuring Brinell hardness, tensile strength and electrical conductivity. The results are discussed with regard to the theories of refining prevalent to-day.

Die Technologische Bedeutung der Gase in Metallen. E. H. SCHULZ. *Zeitschrift für Metallkunde,* January, 1929, pages 7–11.

Paper read at the Deutsche Gesellschaft für Metallkunde, General Convention, Dortmund, June, 1928. Kind and form of occlusion of gas by metals is taken up; also the characteristics of gases as constituents of alloys. Formation of blow-holes on liberation of gases, the technical importance of blow-holes and of the refining phenomena effected by them, is given. Elimination of blow-holes, influence of oxygen on this technical quality of metals, especially of steel, occlusion of hydrogen by iron in refining processes and scaling are further subjects considered.

Technische Eigenschaften Vakuumgeschmolzener Metalle. W. ROHN. *Zeitschrift für Metallkunde,* January, 1929, pages 12–18.

Paper read at the Convention of the Deutsche Gesellschaft für Metallkunde, Dortmund, June, 1928. First suggestions to subject metals to a treatment in vacuum for technical purposes, by bringing molten metal into a vacuum chamber without further supply of heat. Melting in vacuum in leaky furnaces means "oxidation;" success is only possible in practically absolutely tight furnaces. Gases in metals. Gases liberated from liquid metals under vacuum and their origin. Feeding at melting in vacuum. Progress. Products which can be produced already to-day on a technical scale by melting in a vacuum. Sizes of furnaces and weight of charges so far attained, yearly production 1917 to 1928.

Zur Prüfing Von Farbanstrichen. E. RITTER. *Korrosion und Metallschutz,* March, 1929, pages 64–67.

Paints which are used in the potash industry are subject to especially strong attacks, besides the usual ones by air and light, whether by the presence of potash or potash dust. A special method is described to determine various reactions; the tests have not yet been concluded.

Beitrag zur Korrosion des Messings. MAX HAAS. *Korrosion und Metallschutz,* February, 1929, pages 25–35.

A very detailed description of corrosion in brass and methods of protection are given, relations between grain size and corrosion and influence of heat treatment are discussed and analyzed and methods of prevention are proposed. A useful list of publications on this subject is given.

Einfluss des Verformungsgrades Von Bronze auf die Korrosionsbeständigkeit. W. KOHLER. *Korrosion und Metallschutz,* February, 1929, pages 35–41.

Test results of the Bergman Elektrizitäts-gesellschaft on the influence of the difference in structure created by heat treatment on the resistivity to several chemical reagents are given. The interconnection between degree of deformation, grain size and resistance to corrosion are fully investigated and results reproduced in numerous tables and photographs of metallographic tests.

Die Umwandlung der β-Phase in Zink-Kupferlegierungen. P. SALDAU. *Zeitschrift für Metallkunde,* March, 1929, pages 97–98.

The reasons for the non-agreement of results of experiments by different investigators are discussed in detail; the differences are mainly due to differences in the heat-treatment of the material used.

Ueber die Widerstandsfähigkeit Einiger Stähle Gegenüber Chemischen Einflüssen in Abhängigkeit Von Kohlenstoff-, Nickel- und Chrom-Gehalt. FRITZ SCHMITZ. *Zeitschrift für Metallkunde,* February, 1929, pages 64–65.

An investigation was carried out to determine the influence of different contents of Co, Ni and Cr in steels on the chemical resistivity to a great number of organic and inorganic agents. The results are given in a detailed table.

Prüfverfahren zur Beurteilung der Korrosionsbeständigkeit von Metallen gegen Witterung und Seewasser. E. RACKWITZ & ERICH K. O. SCHMIDT. *Korrosion und Metallschutz,* January, 1929, pages 7–13.

The authors advocate an international agreement on the standardization of testing corrosion and discuss the necessary requirements, and describe a few testing methods for determination of corrosion. A quick test method is discussed, then test in solutions in various forms, and finally the evaluation of the test results. The following changes of the samples are determined: 1, surface including cutting edge; 2, weight; 3, structure; 4 tensile properties.

Versuche über Korrosion Von Aluminum und Vergütbaren Aluminium-Legierungen. W. SCHWINNING & H. JAHN. *Korrosion und Metallschutz,* March, 1929, pp. 49–58.

A very detailed communication of tests carried out in the Institut für Metallurgie und Materialprüfung of the Technische Hochschule of Dresden. The results are given in tables and diagrams. Special attention has been directed to the formation of protective films as they are of particular importance in aluminum and its alloys. The loss of weight and the results of bending tests after chemical influences have acted are discussed; according to the testing method used different results can be obtained. Quick-tests are to be used only with great discretion, and tests which approximate as much as possible actual conditions in later operation should be made as often as possible.

Korrosionen Bei Zentrifugalpumpen. R. W. MÜLLER. *Korrosion und Metallschutz,* March, 1929, pages 59–61.

Corrosion in centrifugal pumps, and often in hydraulic turbines, can sometimes not be fully explained. In many cases they are due to purely chemical actions, as in acid pumps; but very often a chemical-mechanical action gives rise to corrosion. Also electrolytical influences may occur. The means for preventing corrosion by proper selection of materials used in the construction and in the arrangement of pumps and machines are thoroughly discussed.

Ueber den Ferroxyl-Indikator. W. VAN WULLEN SCHOLTEN. *Korrosion und Metallschutz,* March, 1929, pages 62–64.

Description of tests on rough and polished samples of iron.

Ueber Schädliche und Nützliche Wirkungen der Gase im Stahl. F. RAPATZ. *Zeitschrift für Metallkunde,* March, 1929, pages 89–93. Discussion.

Oxygen is this cause of hardness susceptibility and of soft spots during hardening. Nitrogen within the limits occurring in steel is harmless. It is advantageously used for case-hardening either by itself or in conjunction with carbon. The development of gas in solidifying promotes the formation of small crystals.

Ueber Die Vergütung Von Standardsilber. MAX HAAS & DENZO UNO. *Zeitschrift für Metallkunde,* March, 1929, pages 94–96.

The results of A. L. Norbury and W. Fraenkel with copper-silver alloys of this type of the English Standard silver (92.5% Ag and 7.5% Cu) have been checked with the differential dilatometer and with the microscope. The mechanism of reheating of refined standard silver is explained.

Vacuum Melting. *Metallurgist,* Feb. 22, 1929, pages 26–27.

Reviews work of Dr. Rohn in which casting, into water-cooled molds, is also carried out under high vacuum.

Die Aufnahme Von Gasen Durch Metalle. A. SIEVERTS. *Zeitschrift für Metallkunde,* February, 1929, pages 37–46.

Paper read at the convention of the Deutsche Gesellschaft für Metallkunde, Dortmund, June, 1929, in the series of lectures on: "Gases in Metals." The capacity of metals and alloys to retain in solution oxygen, nitrogen, rare gases, sulphur dioxide and hydrogen is treated in the light of our present knowledge. In an appendix numerical data are tabulated on the solubility of gases in metals.

Die Untersuchung der Gase in den Metallen. W. Hessenbruch. *Zeitschrift für Metallkunde,* February, 1929, pages 46–57. Discussion.

Paper read at the convention of the Deutsche Gesellschaft fü Metallkunde, Dortmund, June, 1928, in the series of lectures on: "Gases in Metals." This article considers the importance of impurities, the methods of determining gases and the description of necessary apparatus, with some test results. Different types of combinations in which the gas can occur in solid metal are discussed and the various methods of determining this gas suitable for the various purposes are given. The individual methods are briefly described, their characteristics and reliability and the application for the several metals mentioned. A few results of gas determinations for Cu, Ni, Al, Zr and Fe with the melting method in vacuo are given.

Neuere Dilatometrische Untersuchungen. Max Haas. *Zeitschrift für Metallkunde,* February, 1929, pages 58–63. Discussion.

Paper read at the 10th Convention of the Deutsche Gesellschaft für Metallkunde, June, 1928, Dortmund. By means of curves, a comparison of the new mechanical differential dilatometer of Chevenard with the optical differential dilatometer is given. Curves obtained with technically important light and heavy metal alloys are given. Alloys of aluminum-lautal, electron-silicon, aluminum-copper piston alloy and copper-beryllium alloys are considered.

Messing und Sondermessing. W. Wunder. *Zeitschrift Verein Deutscher Ingenieure,* Feb. 2, 1929, pages 165–168.

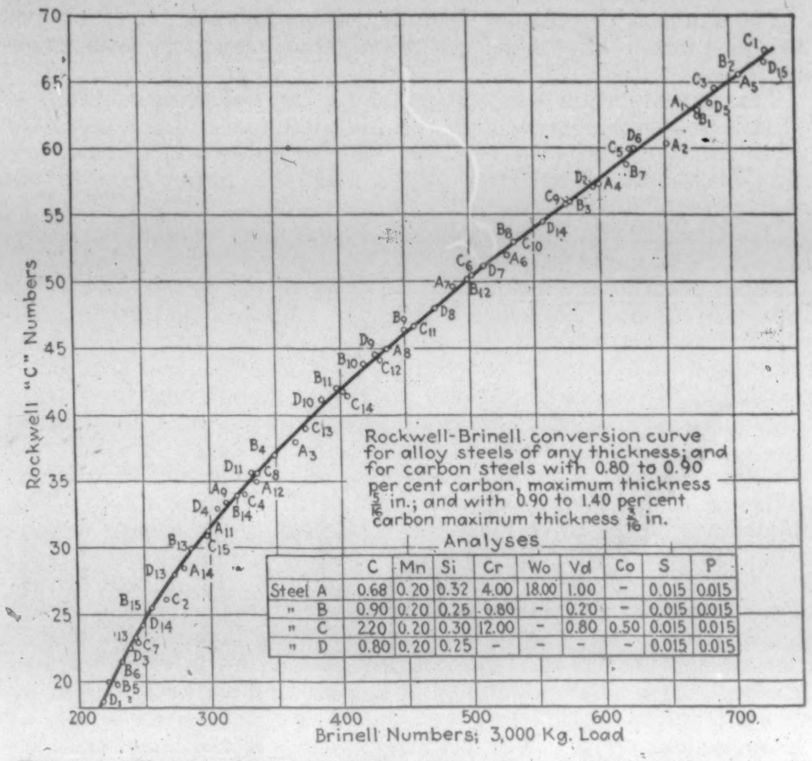
This article compares old and new processes of making zinc-copper alloys. Constitutional and structural diagrams are given. Strain-free formation in which state and ranges of application of α- and $\alpha + \beta$-brasses. Differences in structure at beginning and end of an $\alpha + \beta$ pressed rod and the difficulties occurring hereby at further strain-free shaping. Recrystallization phenomena of α-brasses at different degrees of elongation and temperatures. Bursting of cold-worked, semi-finished brasses and elimination of danger of bursting by mechanical and thermal treatment of the products. Improvement of qualities of brasses by additions is discussed. Calculation of approximate structure. Rules for correct determination of additions. Production of special brasses by means of pre-alloying. Range of application and the usual types.

Anwendungen des Spektrographen in der Metallindustrie. F. Twyman, E. Honegger and D. M. Smith. *Zeitschrift Verein Deutscher Ingenieure,* Feb. 9, 1929, pages 196–200.

Advantages of spectrographic method of analysis especially by ultra-violet rays are given. The variation of numbers and thickness of lines lead to a determination based on numbers. Examples of recent spectrographs and spectroscopes are given. The material to be examined must be brought to luminescence. Immediately superposing spectra are especially advantageous for comparison. This method is more suitable for non-ferrous metals than for steels since iron shows a very complicated spectrum; by using photometric methods, spectral analysis becomes applicable also for alloys containing iron.

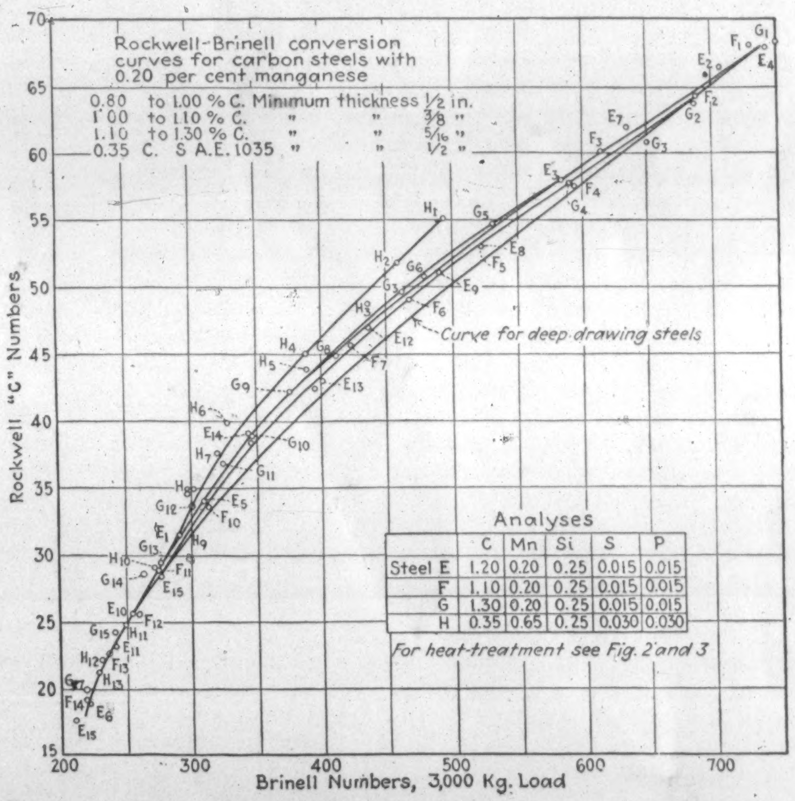
Conversion of Hardness Numbers. Alfred Heller. *American Machinist,* April 4, 1929, pages 536–539, April 11, 1929, pages 583–586; April 18, 1929, pages 633–637.

The prevailing use of both Brinell and Rockwell tests requires a dependable conversion table for the two systems. Existing tables are reasonably accurate for the range of Rockwell "B" scale, but exhibit wide discrepancies in the "C" scale (corresponding to Brinell 244–740, and this including the entire range of heat-treated steels in which hardness requirements are most rigorous). Heretofore, the results attained by skilled workers have not always been in agreement; this is partly due to the fallacy of attempting to develop a single conversion table for all types of steel. Figure 1 indicates the feasibility of constructing a single chart for all deep-hardening steels, while Figure 2 reveals the impossibility of preparing such a chart for other types of steel. Figure 1, based on samples varying widely in content of carbon and other elements, gives evidence that chemical composition has no effect on Rockwell-Brinell conversion values. Accurate results depend largely on proper heat treatment and on care and judgment in subsequent grinding. With various steels, soft spots may result from improper quenching, or from hardening heat which is unevenly distributed, too prolonged, or too high in temperature. Results are recorded for an investigation undertaken by Wilson-Maeulen Co., with tests checked by another laboratory. Results are explained in part by the facts that (1) cold working increases the hardness of steel in a variable way depending on the initial hardness, and that (2) a sudden change in the direction of flow of steel under pressure will result in an increase in the effect of cold working. When subjected to pressure sufficient to cause it to flow, steel does not act as a true liquid, but pressures are cumulated on those surfaces which produce more or less abrupt changes in direction of flow of metal. Accepting the slip-interference theory of hardening, increase in hardness is due to comparatively large grains of unworked steel breaking up into smaller grains as a result of cold working. It may therefore be concluded that steel, flowing under pressure, will increase in hardness to an extent varying with the initial hardness and with the amount of cold work. Increase in hardness due to cold working varies not only with depth of impression, but by reason of changes in direction of flow at different depths of impression. The average unit pressure of Rockwell impression is greater than the average pressure of a Brinell impression of equivalent hardness. Both the Rockwell and Brinell indenting tools change the hardness of steel in making a test. For high Rockwell readings, the increase in hardness caused by making the impression is much greater than the increase in hardness due to the cold work performed by the Brinell ball on the same steel. This is due primarily to the rounded apex of the Rockwell cone.



	C	Mn	Si	Cr	Wo	Vd	Co	S	P
Steel A	0.68	0.20	0.32	4.00	18.00	1.00	-	0.015	0.015
" B	0.90	0.20	0.25	0.80	-	0.20	-	0.015	0.015
" C	2.20	0.20	0.30	12.00	-	0.80	0.50	0.015	0.015
" D	0.80	0.20	0.25	-	-	-	-	0.015	0.015

Figure 1—Showing that a sing le conversion chart or table can be prepared] for deep-hardening steels



	C	Mn	Si	S	P
Steel E	1.20	0.20	0.25	0.015	0.015
F	1.10	0.20	0.25	0.015	0.015
G	1.30	0.20	0.25	0.015	0.015
H	0.35	0.65	0.25	0.030	0.030

Figure 2—Showing that a single conversion chart cannot be prepared for steels that are not deep-hardening

Einige Neue Versuche zur Herstellung Synthetischer Körper aus Metallpulvern. F. Sauerwald. *Zeitschrift für Metallkunde,* January, 1929, pages 22–23.

Paper read at the general convention of the Deutsche Gesellschaft für Metallkunde, Dortmund, June, 1928. Improvement of the qualities of synthetic bodies by pressing at elevated temperature is taken up.

Physikalisch Chemische Grundlagen des Lötens. L. Rostsoky and E. Lüder. *Zeitschrift für Metallkunde*, January, 1929, pages 24–26.

This investigation was instigated by the Soldering Committee of the Deutsche Gesellschaft für Metallkunde and discusses the three kinds of diffusion occurring during soldering, the thermal after-treatment of soldered places and the importance of the melting point of the solder.

Das Giessen von Stahlblocken. F. Pacher. *Stahl und Eisen*, May 2, 1929, pages 627–643.

Paper read before the Annual Meeting of the Verein Deutscher Eisenhüttenleute, Düsseldorf, May 5, 1929. This article compares the importance of the teeming procedure with the melting procedure. The object of pouring is considered—casting, ingot pouring. The more important pouring methods and their basic differences are given. Thermal, metallurgical and mechanical viewpoints. Temperature relations in the pouring and solidifying of different kinds of steels. Possibility of temperature regulation. Influence of heat transmission through the casting mold. The importance of the pipe question. Different types of pipe formation. Quiet and effervescing steel. Means of counteracting pipe. Mechanical pressure methods. Segregations. Blow hole formation. Defects from metallical forces. Shrinkage cracks, cross-section cracks and longitudinal cracks. Slag inclusions. Favorable application for top and bottom casting, its advantages and disadvantages. The possibility of a combined method of pouring is considered.

Beurteilung von Werkstoffen nach Kerbversuchen. W. Schwinning. *Zeitschrift des Vereines Deutscher Ingenieure*, March 9, 1929, pages 321–329.

This article considers the notching effects with elastic deformation (stresses during working) and notching effects with plastic shaping (forced stresses). Influence of type of fracture. Separating fracture and re-inforcing fracture. Procedure of the fracture as a function of temperature and deformation velocity. Influence of change of notching effect on this fracture. The question of standardization of the notched-bar impact test.

Interkristalline Korrosion des Nickels. W. Köster. *Zeitschrift für Metallkunde*, January, 1929, pages 19–21.

Evidence of harmful action of sulphur-bearing gases on nickel is given. The reaction proceeds along the grain borders, therefore causing inter-crystalline brittleness. Microscopic investigation of changes in structure and the practical importance is taken up.

Elektrische Glühöfen für Metalle. M. Tama. *Zeitschrift für Metallkunde*, March, 1929, pages 77–86. Discussion.

Importance of electric annealing furnaces as regards metallurgy and economy. Their equalizing and output increasing influence on economy of electrical energy. Constructions of electric annealing furnaces for metal tubes, metal ribbons, punched parts, of electric reheating furnaces for raw material to be pressed and of electric dipping soldering furnaces in the manufacture of bicycles.

Die Korrosion des Eisens in Chlornatrium-Lösung. W. Van Wüllen. *Stahl und Eisen*, Feb. 14, 1929, pages 212–213.

If two iron-electrodes, one with rough surface, the other with smooth surface, are placed in a sodium-chloride solution an electromotive force is generated which causes current to flow from the smooth negative to the rough positive electrode in the solution. This behavior is, however, largely dependent on the condition of such a cell, stirring of the electrolyte may even cause a reversal of current. The potentials of mentallic iron to ferrous-hydroxide and ferric-hydroxide were measured as 0.569 volt and 0.22 volt, respectively.

Wärmebehandlung und Prüfung von Schnellarbeitstahl Werkzeugen. F. Rapatz. *Stahl und Eisen*, Feb. 21, 1929, pages 250–255.

Particular difficulties met with twist drills, milling cutters, etc., are due to high hardening temperatures. Barium chloride and boric acid salt baths. Tempering to 500° to 600°C. Possibilities of testing high-speed tools.

Ueber die Streckgrenze von Stahl Bëi Höheren Temperaturen. F. Korber. *Stahl und Eisen*, Feb. 28, 1929, pages 273–277.

Increase of operating temperatures; higher stresses at higher working temperatures; necessity of investigating the properties of materials at higher temperatures. The elastic limit of steel depends on the temperature. Relation of hot elastic limit to tensile strength at room temperature of materials for boiler-plates. Relation of hot elastic limit to tensile strength of cast steel at room temperature.

Das Einsetzen in Zyansalzbädern. F. Rapatz. *Stahl und Eisen*, March 28, 1928, pages 427–429.

Experiments on the occlusion of carbon and nitrogen at case-hardening in a bath of cyanide salt. Peculiarities and advantages of the method.

Die Metallische Leitfähigkeit und Ihre Veränderung in Magnetischen Feld. P. Kapitza. *Metall Wirtschaft*, May 10, 1929, pages 443–446.

The specific conductivity of a metal is one of the physical constants whose explanation at present is not yet quite satisfactory. The author offers a contribution by measuring the influence of very strong magnetic fields up to 300,000 gauss which he produces by energies of several thousand kilowatts acting for a time of one hundredth of a second. He offers the following theory for the conductivity; the usual equation expressing the increase of the specific resistance in a magnetic field is quadratic. He separates the quadratic part from the linear part and sees in the latter the real, ideal resistance which would be found if absolutely no impurities were present and also if no disturbances in the atomic structures occurred. Both conditions, however, can very rarely be realized; disturbances in the atomic structure are by the outer field and by inner tensions. We find an analogous condition in the disappearance of resistance at very low temperatures as found by Kamerlingh Onnes, where the resistance drops even to zero. In conclusion, an effort is made to show that although very complicated, these phenomena follow a general common law and have a certain relation to the atomic structure.

Die Elektrische Leitfahigkeit von Kupper, Aluminum und Eisen. *Zeitschrift des Vereins deutscher Ingenieure*, May 4, 1929, page 619.

H. Schmidt has investigated in his dissertation Aachen, 1928, (compare *Physikalische Berichte*, **10**, 488 (1929), the relation of electric conductivity on cold-working and heat-treatment and selected for it the most important metals: copper, aluminum, and iron. For copper, the electric conductivity decreases slowly up to a reduction in section of 30% due to drawing; then it decreases further rapidly to a minimum at 50% and increases again quickly. This only holds for low drafts. For aluminum the conductivity decreases almost linear with increasing degree of elongation. For electrolytic iron, as also for soft-iron and steel, the conductivity behaves irregularly with the degree of elongation, and in steel a slow increase seems to occur. In general, the reduction of electric conductivity by cold-working can be explained by inner stresses produced by it, which depend to a large degree on the kind of cold-working. If the inner stresses are made to disappear by heating to a temperature below recrystallization the conductivity again increases in alloys to a larger degree than in pure metals as was proved by respective tests with brass. The recrystallization acts differently in the different materials. Copper which has been spoiled by annealing at high temperatures seems to be able to regenerate to a certain extent by long annealing at low temperatures. The conductivity of annealed aluminum is, in general, only very slightly changed by storage. In soft-iron, the conductivity is independent of grain-size. In steel, the conductivity increases linearly with the contents of carbon, and more so with lamellar pearlite than with spheroidized. On the strength of these results it is pointed out which treatment in a material is required in order to obtain the highest conductivity.

Synthetisches Gusseisen aus dem Elektroofen. *Giesserei Zeitung*, March 15, 1929, pages 161–168.

The authors uses a publication of the Bureau of Mines to show the advantages which the electric furnace offers for the production of superior quality cast-iron and to point out the economies which can be obtained by the electrical production of cast-iron because scrap of low quality can be used which is no good for the cupola or the open-hearth furnace. The experiences during the war especially in producing synthetic pig-iron in the electric furnace are discussed. The same furnace can be used for making cast-iron and steel. This offers practical advantages. The furnace can also be kept in operation during a time when no steel is made. Practical operating experiences are communicated in making synthetic pig-iron in small electric test furnaces from steel scrap and in commercial production of cast-iron from steel scrap in foundries.

Schmiedespannungen, Vergütungsspannungen und Wärmespannungen. G. Sachs. *Metall Wirtschaft*, April 12, 1929, pages 343–347.

If it is necessary to determine the treatment to which a piece of material had been subjected, the usual mechanical, metallographic and chemical tests are often not sufficient. The author has developed a new method to determine the stress condition in cylindrical bodies by measuring the changes of diameter and length which occur if a sample is drilled; from these measurements the distribution of stress was shown to be characteristically different for different treatments. The samples used, tests made, treatment of samples, stresses measured are described and illustrated in numerous diagrams. The effects of different treatments are compared.

Die Weichlote. E. Thews. *Giesserei Zeitung*, April 1, 1929, pages 189–197.

A very comprehensive study on soft soldering materials (fluxes with low melting points). General properties, influence of impurities and of methods of melting the solders are discussed. Flux materials of cadmium, zinc-cadmium, lead-cadmium-zinc and of very low melting point are studied; the results are given.

Translations

Negotiations are now under way which will assure the appearance of translations of articles appearing in foreign publications. Under this arrangement, the readers of METALS & ALLOYS *will be assured of receiving in English, the best articles at almost the same time as they appear abroad instead of three months to one year later.*

A Contribution to the Knowledge on the System Nickel-Iron

By G. F. Sizoo and C. Zwicker, EINDHOVEN, GERMANY

Translated by special arrangement from Zeitschrift für Metallkunde, April, 1929, pages 125–126.

The investigations into the electrical conductivity and the resistance-temperature coefficient of the system nickel—iron are made very difficult, as is known, by the fact that most of the pure nickel-iron alloys cannot be machined so that necessarily manganese[1] or chromium must be added in order to obtain a material that can be machined. We have succeeded in avoiding these difficulties in the following simple manner and to produce a series of alloys of as pure iron and nickel as possible without any additions. The iron used was electrolytic iron by Heräus, the nickel was obtained from the Mond Nickel Company. The total amount of impurities was, in the iron, 0.1% max., in the nickel 0.4%. The material in the desired proportion was heated in a fire clay crucible of an electric furnace about 500° C. above the melting temperature. To avoid oxidation, hydrogen was passed through the furnace. When the metal was melted a quartz tube of about 1 mm. diameter was put into it. This tube was of such a length that it protruded from the furnace. By means of a rubber hose it was connected to a pump. When the valve of the pump was opened, the liquid metal could be made to rise in the quartz tube. In this manner, a metal rod of about 20 cm. length and 1 mm. thickness was obtained in the tube. The rod was freed of the quartz tube by dissolving in hydrogen fluoride and its surface then etched with nitric acid.

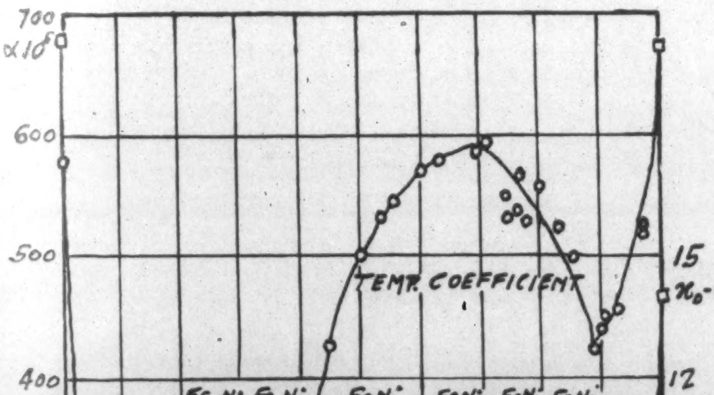


Figure 1—Specific Electrical Conductivity and Temperature Coefficients in System Ni-Fe

It was proved that these rods in many cases consisted entirely or partly of a single crystal. After some experience it was not difficult to obtain in most cases a good and long crystal by properly choosing the rising velocity and temperature. The mono-crystallic structure could be recognized by the familiar shining surfaces (the dislocated reflections) occurring during etching, and could also be proved by several X-ray photographs.

The production of mono-crystals could in this way be effected both for pure nickel as also for nickel-iron alloys even though the nickel content was only 2%. For pure iron this method cannot be used, because of the presence of the crystallographic transformation point. From alloys of about 75 to 80% Ni it was somewhat less easy to obtain the crystals. Perhaps this is due to the formation of the compound $FeNi_3$ (76% Ni) and $FeNi_4$ (80.8% Ni).

Table 1 Specific Electrical Conductivity and Resistance as well as Temperature Coefficient of Ni–Fe Alloys

% Ni	$10^{-4}\,\varkappa_0$ (Ohm. cm.)$^{-1}$	$10^5\,\varrho_0$ Ohm. cm.	$10^5\,\alpha_{0100}$
0	9.75	1.03	580
2.5	5.10	1.96	306
4.0	4.95	2.02	299
6.5	4.10	2.44	244
10.1	3.68	2.72	225
13.4	3.51	2.85	244
20.4	3.61	2.77	260
24.0	3.47	2.88	273
27.2	1.38	7.27	145
33.6	1.31	7.62	126
40.8	1.79	5.58	306
44.8	2.51	3.98	426
50.2	3.40	2.94	500
55.3	4.32	2.32	544
60.3	5.47	1.83	571
62.8	5.81	1.72	585
69.9	7.09	1.41	596
70.0	7.30	1.37	592
74.3	..	..	550
74.8	7.88	1.27	533
76.0	..	..	537
76.1	6.94	1.44	567
78.1	..	..	531
79.8	7.46	1.34	560
82.6	8.06	1.24	525
84.8	8.41	1.19	497
88.8	..	..	425
89.8	8.06	1.26	442
90.9	8.26	1.21	454
92.2	..	..	457
97.3	..	..	518
97.5	..	..	523
100.0	13.8	0.725	617

While the multi-crystallinic parts of the rods, particularly for alloys with more than 60% Ni, could not be machined at all, the mono-crystals did not present any difficulty in drawing or rolling. To measure the electrical conductivity the crystals were drawn into wires of 0.25 mm. After this the wires were annealed in a vacuum furnace at a temperature of 900° and then cooled slowly. The electrical conductivity of these wires was measured at 0° and 100° C. by means of the Kohlrausch method with overlapping shunt. After the measurements the wires were analyzed to determine the nickel content.

---

[1] Dr. Ribbeck, *Zeitschrift für Physik*, **38**, 772 and 887 (1926); here also further bibliography; A. Schultse, *Ibid.*, **50**, 448 (1928).

The values of the specific electrical resistivity and specific electrical conductivity at 0° C. and the values of the resistance temperature coefficient between 0 and 100° C. are tabulated in Table 1.[2] In Fig. 1 are plotted the electrical conductivities and temperature coefficients. The individual points coincide well with the drawn curves. Only in the vicinity of 80% are there a few deviations. This may be due to the previously mentioned difficulty of obtaining these alloys.

The qualitative similarity of the two curves is obvious from Fig. 1. The shape of the curves shows an agreement with the curves of the magnetic transition temperatures.[3] This sharp minimum at 34% Ni (Fe_2Ni_2 = 34.2% Ni) and the shallower maximum at 68% Ni ($FeNi_2$ = 67.8% Ni) can be also formed there. Some of the possible nickel-iron compounds are indicated in Fig. 1. The compounds Fe_3Ni_4, Fe_2Ni and $FeNi_2$ coincide almost exactly with a maximum or minimum of the curves.

Our values for the specific conductivity and temperature coefficient are all considerably higher than the ones measured by A. Schulze for alloys containing manganese, which agrees with the greater purity of our alloys. This holds good particularly for the alloys of high percentage.[4] It does not seem impossible to obtain still higher values of the temperature coefficients for still greater purity of the starting materials. We found the temperature coefficient of the iron used to 0.0058° and that of the nickel 0.0062° while Holborn[5] measured for extremely pure and iron nickel 0.00680, respectively, 0.00675.

Small impurities therefore, already have a considerable influence. By remelting the iron in a vacuum high-frequency furnace the temperature coefficient could be increased to 0.00625. The values of the temperature coefficients of pure iron and nickel according to Holborn are shown in Fig. 1 by circles in parenthesis.

In conclusion we wish to express our thanks to Messrs. H. Ten Hoor and D. F. Coumon for their assistance in this investigation.

[2] In some cases, the measurements have been made on the crystal wires themselves. As the diameters were not sufficiently uniform to calculate the conductivity, the table in these cases gives only the temperature coefficients. A relation of the temperature-coefficient to the crystal size could not be determined.

[3] W. Guertler and G. Tammann, *Zeitschrift für Anorg. und Allg. Chemie*, vol. **45**, 203 (1905); M. M. Peschard, *Comptes Rendus*, **180**, 1475 (1925).

[4] Schulze (p. 449) has also measured the temperature coefficients between 15 and 25° C.) and the electric conductivity (at 20° C.) of eight electrolytic nickel-iron alloys made by Scharnow (E. Gumlich, W. Steinhaus, A. Kussmann and B. Scharnow, *Elekt. Nachrichten. Techn.*, **5**, 93 (1928)). With these values ours agree very well after reduction to the same temperatures.

[5] L. Holborn, *Annalen der Physik*, **59**, 145 (1919).

X-Ray Examination of Aluminum at High Temperatures

By A. J. Alichanow, Leningrad, Russia

Translated by special arrangement from Zeitschrift für Metallkunde, April, 1929, page 127.

In connection with the problems of a refinement of duraluminum the question has been repeatedly asked if an allotropic transformation exists in aluminum. Many investigations have been devoted to this question, which were mostly carried out with dilatometric or electric methods.

LeVerier[1] assigns the temperature 535° C. to this transformation point, Cohen[2] 580°, Lachtschenko[3] 590°, Reimann[4] 575° and O. Tiedemann[5] 560° C. The investigations of recent years, however, speak with increasing reliability against the allotropic transformation in aluminum and explain the presence of discontinuities in the cooling curves and the curves of electric conductivity in connection with the segregation of different additions from the solutions.

Lately, Guertler and Anastasiadis[6] have examined eight kinds of aluminum with different amounts of additions by three methods—dilatometric, electric and thermal and, on the strength of these investigations, no existence of a transformation was determined. M. Haas[7] has found no transformation from 0 to 616° with dilatometric methods. A. Muller[8] also denies it.

A Schulze[9] used the same methods, very pure aluminum (99.94% Al) and did not find any transformation point.

To supplement the investigations on this question, we have carried out an X-ray examination of aluminum at high temperatures. The exposures were made with a vacuum camera of the A. F. Westgren type. The sample in the shape of a wire of 3.5 to 4.0 cm. length and 0.4 to 0.6 mm. diameter was clamped at one end and the other end dipped into a small container with mercury. It was heated by the current of a storage battery of 2 volts.

The test was made in the following manner: a current of a certain strength was passed through the aluminum sample; the current was kept constant during the exposure. After the exposure the camera was again loaded and another slightly larger current sent through the sample, and so forth until at last the aluminum sample melted at a slight additional current.

In order to check the result by relative measurements in a few cases, exposures were made at high and at low temperature on the same film. To obtain more or less continuous lines the sample was rotated during exposure. The pictures were made in CuKα and FeKα.

All exographs show one line system only, which corresponds to the structure of a surface centered cube.

We give as a sample the results of the measurements for three exographs in Table 1.

Table 1

$h_1\ h_2\ h_3$	The distances measured	Lattice constant	Average
111	30, 3 mm.	4.107 A.	
200	35, 1 mm.	4.110 A.	
220	51 mm.	4.106 A.	4.104 A.
311	61 mm.	4.108 A.	+ 0, 005
222	64, 2 mm.	4.100 A.	
331	86, 8 mm.	4.098 A.	
420	90 mm.	4.104 A.	
422	105, 4 mm.	4.101 A.	
111	30, 3 mm.	4.107 A.	
200	35, 1 mm.	4.110 A.	
220	51 mm.	4.106 A.	4.106 A
311	60, 9 mm.	4.109 A.	+ 0, 005
222	64, 2 mm.	4.100 A.	
331	86, 6 mm.	4.106 A.	
420	....	......	
422	....	......	
111	30, 2 mm.	4.110 A.	
200	35 mm.	4.112 A.	
220	50, 9 mm.	4.109 A.	4.110 A.
311	61 mm.	4.108 A.	+ 0, 002
222	64 mm.	4.111 A.	
331, 420, 422	....	......	

It must be emphasized here that the intensity of the lines, especially of the last ones, decreased greatly due to the movement of heat; for instance the last three lines of the third group in the table could not be measured.

At temperatures near the melting point, only the first three or four lines could be used for measurements on account of this effect. Further, the crystals then grew to such a size that even with rotation no continuous lines could be obtained but only single points far distant from one another. This condition also made measurements difficult.

If the heat expansion coefficient for aluminum is assumed to $0.28 \times 10-4$,[10] the temperature in case a = 4.106 A is 557° C. and in case a = 4.110 A 593° C. (if a = 4.045 A at normal temperature).

From these results it can be concluded that, up to 593° C., at any rate, aluminum shows no allotropic transformation.

The aluminum samples tested contained 99.5% Al and were supplied [illegible] the Metallographic Laboratory of the Polytechnic Institu[illegible]f Leningrad.

I feel it a duty to express my thanks to Prof. N. Seljskow for the advice given during this investigation, and to Mr. M. G. Oknow for the aluminum samples.

---

[1] LeVerier, *Comptes Rendus*, **114**, 907 (1892).

[2] E. Cohen, *Proceedings of Academy of Amsterdam*, **17**, 200 (1914).

[3] Lachtschenko (Russian), *Journal of the Russian Physical-Chemical Society*, **46**, 119 (1922).

[4] H. Reimann, *Zeitschrift für Metallkunde*, **14**, 119 (1922).

[5] O. Tiedemann, *Ibid.*, **18**, 18 (1926); compare also **20**, 154 (1928).

[6] W. Guertler and L. Anastasiadis, *Zeitschrift für Physikaliche Chemie*, **132**, 149 (1928).

[7] M. Hass, *Zeitschrift für Metallkunde*, **19**, 404 (1927).

[8] A. Muller, *Ibid.*, **19**, 414 (1927).

[9] A. Schulze, *Zeitschrift für Physik*, **49**, 146 (1928). Report *Zeitschrift für Metallkunde*, **20**, 262 (1928).

[10] Landolt-Börnstein, *Physikalisch-Chemiskche Tabellen*, **1927**.

Book Reviews

Kristallographische und Strukturtheoretische Grundbegriffe. By P. Niggli. 317 pages, 131 figs. Akademische Verlagsgesellschaft, Leipzig, 1928.

This treatise is especially designed for the physicist and the specialist in crystallography. First the laws of static crystal-geometry are mathematically derived and discussed whereby the homogeneous three dimensional discontinnum, this crystal lattice, is at once introduced as constitutional element. In a second chapter, the general numerical and graphical treatment of crystallographic problems follows, then comes the derivation of symmetry qualities and the 32 symmetry classes which can be distinguished thereby. The next chapters deal with the special crystallographic conditions of the 14 kinds of lattices and the analytical-geometrical investigation of the 230 space systems. Taking into account the individual sizes and the capacity of the particles forming the crystal for taking up space, it is shown how a topological structural analysis of crystals can be arrived at. The scientific examination of crystals is in this respect still at its inception, and the author tabulates in conclusion the means leading to geometrical structural analysis. The book contains a great deal of new matter which the author publishes here for the first time, and is an important step toward the solution of the "basic task of the crystallographer which is to determine the structure of a crystal and to bring it into relation with the whole geometrical, physical and chemical behavior of the crystallized substance."—Max Hartenheim.

Vibration Problems in Engineering. By S. Timoshenko. Cloth, 6 × 9, 351 pages, 165 figs. D. Van Nostrand Co., New York, N. Y., 1929. Price, $4.50.

Timoshenko develops fully the theory of vibrations, giving the fundamental equations for broad classes of problems. These he illustrates by various examples, in many cases taken from actual experience with vibration of machines in service. The subject matter is based upon a series of lectures on vibration, which he delivered before the engineers of the Westinghouse Electric & Manufacturing Company in 1925.

The appendix giving a general description of vibration measuring instruments will be the most interesting to Metals & Alloys readers, although the chapters dealing with turbine blade, disk and shaft vibration sum up these problems in a comprehensive manner.—Richard Rimbach.

Proceedings of the Thirty-First Annual Meeting of the American Society for Testing Materials. Published by the Society, 1929. Cloth, Part I, 1184 pages; Part II, 904 pages. Price, $6.50 each.

Part I contains the annual reports of 45 committees on research and standards. Part II, 46 technical papers of pertinent content on materials of construction.

Standards Yearbook 1929. Issued by the U. S. Bureau of Standards. Published by the Government Printing Office, 1929. Paper, 401 pages. Price, $1.00.

Each succeeding issue of the Standards Yearbook records a story of steady progress and accomplishment in the development of practicable commercial standards and their acceptance by a large proportion of industrial organizations. The edition of 1929 is no exception. Besides the general growth of the standardization movement as revealed in the membership, activity and expanding scope of the world's standardizing agencies, there is a section devoted to the work of the National Bureau of Standards, reporting more than two hundred and fifty specific projects in a wide variety of industrial fields, which, through coordination of scientific, industrial and commercial research, have resulted in much valuable information regarding materials, processes, new applications, specifications, methods of test and units of measurement.—D. L. Mathias.

Magnetic Properties of Matter. By Kotaro Honda. 256 pages, 213 figures. Syokwabo & Co., Tokyo, 1928. Price, 6.8Y.

This book by an eminent Japanese scientist is an English revised edition of his book which was published several years ago in the Japanese language. The basic idea and carrying it through can be considered as very fortunate. The clear and lucid subdivision as well as the limitation of the material and the numerous good diagrams of largely his own work make it a modern, up-to-date treatise on magnetism. In the text, all unnecessary calculations and purely theoretical-speculative discussions have been avoided, and in all problems only the actual mathematical proof and the test results are given.

The contents give a survey on magnetism as a property of materials and the application of magnetic methods for their examination. Due to a formal limitation the author excludes the magneto-optic phenomena, etc., from his discussions.

Chapter 1 gives the principles and theories of the magnetization of a body; Chapter 2 the measuring methods and the characteristic properties of ferromagnetic materials. A detailed description of the individual apparatus is, of course, impossible, the data must be restricted to the basic principles. In the subdivision, "Hysteresis" the author has apparently overlooked the publications made during the war by Steinhaus and Gumlich on the ideal, i. e., hysteresis free magnetization. Chapter 3 deals with the relation of magnetism to mechanical deformations; Chapter 4, which unfortunately is a little short, the dependency of ferromagnetic materials on temperature. Chapters 5 and 6 introduce into the proper working sphere of the author, the inter-relation of magnetic phenomena with metallurgical science. The thermal and magnetic phenomena in steel and its alloys and the ferro magnetism of the alloys is treated. Chapter 7 brings Para and Diamagnetism, a review on measuring methods and results. The three last chapters are devoted to theoretical questions on the substance of magnetism and contain also a survey on the present theories, the modern measurements on mono-crystals and on the magnetic momentum of the atoms. Also here, especially in the historical part, the very clear way of expression of the author must be emphasized.

The book can be recommended to all research engineers who have to deal with the physical principles of magnetism.—Richard Rimbach.

Practical Steel Making. By Walter Lister. Cloth, 6 × 9, 413 pages, 211 figs. Chapman and Hall, Ltd., London, W. C. 2, England. (Sold in U. S. by Richard Rimbach, 1117 Wolfendale St., Pittsburgh), 1929. Price, $7.25 postpaid.

A reviewer cannot help himself from trying to find faults in a book which he is reading and usually he succeeds in his intention. At the beginning these defects stand out like a sore thumb until the book is finished, its meaning, purpose and interest are appreciated and balanced against defects in details. Practical Steel Making is remarkably free from them.

One may mildly wonder what calamity would happen if ganister which according to page 34 would have 95.32% SiO_2 is delivered to the plant having 95.34% or so silica. The indiscriminate use of metric and English units cannot be considered as a defect, but rather as a sign of times when the merits of the former are making inroads in the strongholds of tradition.

The book is English both in terminology and subject matter. As long as the writer deals with questions having but one method of approach an American reader can greatly benefit from his description but the introduction of charging of limestone on the top of the charge, continuous doctoring of the slag, patching of the bottom while tapping would easily lead to almost a riot in an American plant.

Mr. Lister honestly tries to give to the reader the familiarity with steel making processes without the usual sweaty schooling on the floor. In this he succeeded admirably.—John D. Gat.

Bibliography of Metallic Corrosion. By W. H. J. Vernon. Comprising references to papers on ferrous and non-ferrous corrosion published up to the end of 1927. Greatly enlarged from a bibliography prepared for the British Non-Ferrous Metals Research Association and privately issued to its members. Cloth, 6 × 9, 341 pages. Longmans, Green & Co., New York, N. Y., 1928. Price, $8.40.

The well-known English corrosion-expert, W. H. F. Vernon, has, with this excellent bibliography of corrosion, concentrated in a handbook with about 3800 separate data, the literature on corrosion which has now grown as extensive as it is dispersed. The book originated from a resumé on corrosion of non-ferrous metals of the British Non-Ferrous-Metals Research Association of 1921 and has been enlarged before being printed to include the corrosion of iron and its alloys.

All literature up to the end of 1927 has been taken into consideration. The outstanding literature can be easily looked up in the *Journal of the Institute of Metals* or *Journal of the Iron and Steel Institute*, in *Stahl und Eisen*, *Zeitschrift für Metallkunde*, and *Korrosion und Metallschutz*.

The literature goes very far back; for example, for aluminum until 1874, copper 1835, lead 1852.

Vernon has been very fortunate in the selection of divisions and titles. The clear practical division consists of:

Part 1—General considerations (different kinds of corrosion, factors influencing corrosion). Part 2—Reagents of corrosion. Part 3—The metals (the metal, the alloy or the finished product which are subject to corrosion or resist it). Part 4—Protection against corrosion.

The suitable alphabetical sequence of headings and the chronological subdivision of minor points is very practical. If the literature on influence of grain size on corrosion is desired, one will look in general in Part 1, sub-chapter, "grain size," and find there chronologically arranged a vast amount of information on the influence of grain size in different metals and alloys.

Part 1 contains concentrated on page 70 the most valuable definition of the basic conception of corrosion and methods.

Part 2 is valuable for the chemical industry, giving an ideal review of the different agents in relation to corrosion of the material, included are gases and atmosphere.

Part 3 is particularly interesting to the practical engineer and technologist. This chapter is especially carefully prepared, and offers, together with the concluding chapter on protection of metal, the possibility of looking over this whole great field from the "bird eyeview," as Vernon himself says. If Vernon's book should bring about a saving of time and promote productive collaboration, a very important aim will have been achieved.—F. M. Turner, Jr.

Methodes et Procedes Metallurgiques. By M. Regnauld. Paper, 6 × 10, 342 pages. Gauthier-Villars & Co., Paris, France, 1929. Price, 60 Fr.

A textbook on ferrous metallurgy. The raw materials, refractories, ferrous alloys, fuels and methods of mechanical treatment are described concisely.—Max Hartenheim.

Zugfestigkeit und Härte bei Metallen. By Otto Schwarz. 34 pages, 51 figs. and 20 tables. V. D. I. Verlag, Berlin, 1929. Price, 6 R. M.

Values for the conversion of Brinell-hardness numbers into tensile strength values vary in such wide limits that, in most of the non-ferrous metals, some steel-alloys and in cast metals, the practical evaluation of a relation between hardness and tensile strength becomes impossible.

Schwarz, in his treatise, offers a contribution to the elucidation of the question as to the reason for the variations, and concludes that a linear relation between the two constants is impossible. Numerically, a fairly complicated relation of tensile strength to hardness can be obtained by making simple assumptions, the graphical evaluation of which permits a conversion with an accuracy of 5%. For metals at higher temperatures the same holds. The investigation which was instigated by R. Baumann contains numerous numerical data and also gives valuable information for the standardization of non-ferrous metals.—Max Hartenheim.

Photomicrographs of Iron and Steel. By Everett L. Reed, S.B., Instructor in Metallurgy at Harvard University, with a foreword by Dr. Albert Sauveur, Gordon McKay Professor of Metallurgy and Metallography at Harvard University. Cloth, 6 × 8, 253 pages, 218 figures. John Wiley and Sons, 1929. Price, $4.00.

The appearance in metallurgical literature of the book, or rather album, of Mr. Reed is more than an addition of another interesting work, it is symptomatic of the situation developing in the metallurgical world similar to that existing in chemistry when investigators tried to get away from terms "slightly acid," "decidedly alakline," etc., substituting them with a definite value of hydrogen ion concentration. The need for an authoritative metallographic ABC permitting independent workers to speak the same language has been long felt, as can be seen from the favorable reception given to the Microstructure Chart of SAE Steels by Dr. Sauveur and the author of this book.

The photographs which are the real substance of this work are well made. Polishing is good with a few slight exceptions as well as lighting which could be improved only in a very few instances. It is difficult to say whether the tendency for stepping down too much at moderate magnifications reflects the individual preference of the author or is due to the peculiarities of optical equipment used. There seems to be no necessity for over-etching some of the specimens to show their structure clearly.

The presentation of the subject would gain if, instead of illustrating a treatment with several steels of casual composition, a few of them are selected and subjected to different treatments as it is done with 0.50 carbon steel. A little more definite captions would help to prevent misunderstanding when, as for example on Fig. 6, several inclusions are shown and only one mentioned.

On the whole the book is well printed with only a few mistakes in proof-reading, gives much interesting information, including the description of up-to-date practice and while not bringing anything new to a metallurgist with a broad experience, it can be of great value to one less familiar with the subject or only occasionally coming in contact with some of the subjects treated in it.—John D. Gat.

Messen und Wägen. By Walter Block, with introduction by Fritz Plato. 339 pages, 109 figs. Otto Spamer, Leipzig, 1928. Price, 28 R. M.

The book has intentionally assumed the character of a treatise and is intended especially for the chemist, physician, etc., who only occasionally have to carry out the more difficult measurements.

In the introduction, Plato describes the development of the measuring science and of weights and measures, which led to the German regulations for weights and measures based on international agreements.

The next chapters of the book give general discussions on measurements and measuring systems, further directions for the measurements of time, angles, length and area are given. A particularly large part of the book is devoted to determinations of volume, weighing and measuring density, as this is especially important for the chemist. Numerical examples facilitate comprehension. In the chapter on temperature measurements, the instruments required for the determination of temperature—gas, mercury and resistance thermometers, thermocouples and radiation pyrometers—are described. Justly, Block emphasizes that special care should be given to the installation of measuring devices, particularly if they are to be used for measuring gas temperatures. In discussing the devices for measuring heat, the heat-flow meter of E. Schmidt should be mentioned, in addition to the apparatus for determining heating value, as this is fairly important for the chemical engineer. In conclusion, a few data are given on optical and electrical measurements. Literature on measuring methods is covered in a comprehensive index.—Richard Rimbach.

Materials Handbook. By George S. Brady. Fabrikoid, 4 × 7, 428 pages. McGraw-Hill Book Company, New York, 1929. Price, $4.00.

A convenient little reference book on abrasives, metals and alloys, building materials, fibres, textiles, paints, chemicals, oils, minerals and woods used in industry. The materials, arranged alphabetically, are briefly described, with some indications of their properties and uses. A valuable feature is the inclusion of many new proprietary alloys.—Richard Rimbach.

Patent Department

Through an arrangement with Mr. W. M. Corse, Metallurgical Engineer, Washington, D. C., who operates a well-known Patent Information Service, we are able to publish every month a list of important patents in the metallurgical field from the United States and Europe. The following countries will be included in the European listing: England Germany, France, Switzerland, Denmark, Norway, Sweden and Italy.

If our readers wish more information about any of the patents listed below they can get it by writing to our Patent Department, and mentioning the fact that they have seen the reference in METALS & ALLOYS. We will be prepared to mail copies of United States Patents to clients within twenty-four hours of date of issue by special arrangement. Photostatic copies, translations of claims and of full text of foreign patents will be supplied if desired.

This service is furnished under special arrangement with Mr. Corse's organization at most reasonable rates. Full information can be secured by writing to Patent Department, METALS & ALLOYS, 419 Fourth Avenue, New York.

United States Patents

Patents issued from May 21 to June 11, 1929, inclusive.

Patent No.	Patentee, Subject of Invention, and Filing Date
1,713,507	C. D. Ammon, Lincoln, Nebr. Hammer mill. Aug. 16, 1928.
1,713,514	R. Appel, Berlin, Germany. Process of electrolytically separating metallic chromium for the production of chromium coatings on other metals. Aug. 3, 1926.
1,713,543	A. W. Machlet, Elizabeth, N. J. Furnace for melting metals. Apr. 15, 1926.
1,713,580	H. M. Williams, Dayton, Ohio, assignor to General Motors Research Corp., Dayton, Ohio. Process of producing high-heat-resisting substances. Jan. 10, 1925.
1,713,653	J. H. Gravell, Elkins Park, Pa., assignor to American Chemical Paint Co., Ambler, Pa. Metal cleaning. June 22, 1926.
1,713,677	K. Schumpelt, Pforzheim, Germany, assignor to E. G. Bek, Pforzheim, Germany. Process of soldering and product thereof. Oct. 9, 1926, in Germany Sept., 1924.
1,713,699	A. T. Keller, Bethlehem, Pa., assignor to Bethlehem Steel Co., Bethlehem, Pa. Process of making car-wheel rims. Oct. 18, 1921.
1,713,766	G. G. Marshall and H. S. Booth, Cleveland, Ohio. Alloy (Fe-Cr-Be). Feb. 27, 1923.
1,713,770	J. R. McWane, Birmingham, Ala., assignor to McWane Cast Iron Pipe Co., Birmingham, Ala. Means for handling and mechanically ramming flasks. Dec. 12, 1924, renewed Oct. 2, 1928.
1,713,790.	W. A. Timm, Berwyn, Ill., assignor to Western Electric Co., Inc., New York, N. Y. Apparatus for heat-treating metals. Nov. 15, 1926.
1,713,845	E. A. Lockwood, Royal Oak, Mich., assignor to American Electrical Heater Co., Detroit, Mich. Electric soldering iron. Nov. 22, 1926.
1,713,869	W. Fisher, Bryn Mawr, Pa. Apparatus for preparing molding sand. Aug. 28, 1925, continuation of application filed Apr. 6, 1922.
1,713,887	A. J. Briggs, Syracuse, N. Y., assignor to Onondaga Steel Co., Inc. Production of wrought iron. Dec. 8, 1926.
1,713,957	S. Duvall, Chicago, Ill. Pulverizing mill. June 20, 1928.
1,713,962	J. Grossweischede and G. Reichenbecher, Mulheim-on-the Ruhr, Germany, assignors to Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. Collapsible draw mandrel. Jan. 24, 1927, renewed Mar. 20, 1929.
1,713,965	F. J. Hull, Hagerstown, Md., assignor to Pangborn Corp., Hagerstown, Md. Sand-blast table. July 14, 1927.
1,713,974	H. F. Massey, Disley, England. Forging press or like machine. Mar. 6, 1924, in Great Britain Mar. 9, 1923.
1,713,995	W. B. Chapman, Jackson Heights, N. Y., assignor to The Chapman-Stein Furnace Co., Mount Vernon, Ohio. Continuous push furnace. Aug. 2, 1924.
1,714,007	W. E. Endrezze, Butte, Mont. Ore classifier. Sept. 17, 1927.
1,714,035	C. Mauler, Vienna, Austria. Process for ascertaining the resistance to rusting shown by iron, steel and iron alloys. July 11, 1927, in Austria July 22, 1926.
1,714,038	A. F. Murphy, Zanesville, and W. Jones, Middletown, Ohio, assignors to The American Rolling Mill Co., Middletown, Ohio. Process of treating silicon steel. Apr. 15, 1927.
1,714,040	H. M. Naugle and A. J. Townsend, Canton, Ohio, assignors, by mesne assignments, to The Columbia Steel Co., Pittsburgh, Pa. Continuous annealing process. Apr. 4, 1924, renewed Oct. 13, 1928.
1,714,081	F. A. J. Fitzgerald, Niagara Falls, N. Y., assignor to Harper Electric Furnace Corp. Electric furnace. May 13, 1927, division of application filed May 26, 1925.
1,714,084	J. Gassen, Düsseldorf-Rath, Germany. Rolling mill. Jan. 15, 1925, in Germany Jan. 15, 1924.
1,714,131	A. G. McHugh, Youngstown, Ohio. Mandrel changing and cooling machine. Jan. 11, 1928.
1,714,171	A. F. Jobke, Pittsburgh, Pa. Magnetic separator. Jan. 12, 1926.
1,714,177	L. W. Mallasee, Pittsburgh, Pa., assignor to W. H. Mallasee, Pittsburgh, Pa. Ferrous alloy. Sept. 22, 1927.
1,714,280	S. E. Sieurin, Höganas, Sweden. Process for the production of iron sponge. Dec. 17, 1927, in Sweden Jan. 26, 1926.
1,714,385	W. L. Lofthouse, Los Angeles, Calif. Electric soldering iron. Dec. 22, 1927, renewed Apr. 1, 1929.
1,714,445	W. Reuss, Mannheim, Germany. Soldering and welding medium for aluminum. June 23, 1928, in Germany Feb. 15, 1928.
Re 17,309	A. C. Zimmerman, Dayton, Ohio, assignor to The Dow Chemical Co., Midland, Mich. Treatment of magnesium and magnesium alloys to inhibit corrosion. Mar. 9, 1929. (Original No. 1,677,667, filed Oct. 31, 1924, issued July 17, 1928.)
1,714,506	R. P. Heuer, Philadelphia, Pa., assignor to General Refractories Co. Brick and cement for furnace use. Dec. 29, 1924.
1,714,564	W. Koehler, Cleveland, Ohio. Antifriction and antiabrasive metal. Aug. 1, 1927.
1,714,615	P. Naumann, Dresden-Blasewitz, and K. Weber, Dresden, Germany. Soldering iron. Dec. 24, 1927, in Germany Dec. 29, 1926.
1,714,664	C. E. Foster, Letchworth, England. Radiation pyrometer. July 9, 1925, in Great Britain Nov. 15, 1924.
1,714,667	H. Harris, London, England. Treatment of solutions containing tin and arsenic for precipitation of tin. Sept. 9, 1925, in Great Britain, Sept. 18, 1924.
1,714,668	C. B. Higgins, H. A. Higgins and J. Tyler, Detroit, Mich. Apparatus for cleaning metal. Jan. 2, 1926.
1,714,679	D. C. Lee, Spokane, Wash. Alloy (antifriction). Nov. 17, 1926.
1,714,729	F. J. Read, San Francisco, Calif., assignor of one-half to Calaveras Iron and Steel Co., and one-half to S. H. Demarest, San Francisco, Calif. Metal (Cu-Al-Ce). Sept. 28, 1927.
1,714,767	A. J. F. J. Cousin, Jemeppe sur Meuse, Belgium, assignor to Société Anonyme John Cockerill, Seraing, Belgium. Process for the reduction of metallic oxides. Mar. 14, 1923, in Belgium May 18, 1922.
1,714,781	C. M. Henderson, Oakland, Calif., assignor to H. C. Macaulay Foundry Co., Berkeley, Calif. Molding machine. Aug. 24, 1926.
1,714,826	J. A. Toleik, West Orange, N. J., assignor to American Can Co., New York, N. Y. Electric soldering means. Jan. 30, 1926.
1,714,828	J. T. Travers, Columbus, Ohio, assignor to The Travers-Lewis Process Corp., Columbus, Ohio. Process and apparatus for treating acidified mine water. July 9, 1928.
1,714,867	A. R. Gross, St. Paul, Minn., assignor to Gross Metal Products Co., St. Paul, Minn. Welding apparatus. July 2, 1927.
1,715,017	G. A. Thornton, Schenectady, N. Y., and W. Remington, Swampscott, Mass., assignors to Thomson Welding Co., Lynn, Mass. Electric welding apparatus. Mar. 12, 1927.
1,715,099	W. J. Robinson, Lowell, Mass., assignor by mesne assignments to Winchester Repeating Arms Co., New Haven, Conn. Metal tube and method of making same. Nov. 20, 1922.
1,715,155	S. Westberg, Pittsburgh, Pa. Method of reducing oxides or oxide ores. June 27, 1925.
1,715,219	F. C. Biggert, Jr., Crafton, Pa., assignor to United Engineering and Foundry Co., Pittsburgh, Pa. Apparatus for stretching and coiling strip material. Sept. 25, 1926.
1,715,262	C. B. White, Philadelphia, Pa. Salvaging storage-battery electrodes. Aug. 9, 1927.
1,715,316	C. B. Thwing, Philadelphia, Pa., assignor to Thwing Instrument Co., Philadelphia, Pa. Thermopile. Mar. 21, 1925.
1,715,317	A. Vuilleumier, Bristol, Conn., assignor to The New Departure Manufacturing Co., Bristol, Conn. Heat-treating apparatus. May 7, 1927.
1,715,330	N. C. Rendlemen, Dormont, Pa., assignor to Jones & Laughlin Steel Corp., Pittsburgh, Pa. Rolling wide strips. July 1, 1926.
1,715,355	F. Graf, South Bend, Ind., assignor to American Foundry Equipment Co., New York, N. Y. Sand-cutting machine. Aug. 17, 1926.
1,715,357	W. F. Hall, Matawan, N. J., assignor by mesne assignments to Hanson-Van Winkle-Munning Co., Matawan, N. J. Electroplating machine. Aug. 19, 1926.
1,715,376	J. E. McLaughlin, Berlin, N. H., assignor to Brown Co., Berlin, N. H. Electrode installation for electric furnaces. Apr. 29, 1925.

Patent No.	Patentee, Subject of Invention, and Filing Date
1,715,411	N. P. Di Cesare, Sheboygan, Wis., assignor to Kohler Co., Kohler, Wis. Electroplating rack. Aug. 22, 1927.
1,715,418	F. C. Langenberg, New York, N. Y., assignor of one-half to F. H. Morehead, Boston, Mass. Machine for making castings. Nov. 28, 1925, renewed Oct. 17, 1928.
1,715,421	F. H. Morehead, Boston, Mass., assignor of one-half to F. C. Langenberg, Watertown, Mass. Machine for making castings. Nov. 28, 1925, renewed Oct. 12, 1928.
1,715,449	T. S. Curtis, Huntington Park, Calif., assignor by mesne assignments to Pacific-Southwest Trust & Savings Bank Trustee, Los Angeles, Calif. Refractory composition and process of making the same. Dec. 11, 1924.
1,715,509	E. Piwowarsky, Aachen, Germany, assignor to Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. Process for obtaining cast iron. June 17, 1927, in Germany June 15, 1926.
1,715,541	G. W. Elmen, Leonia, N. J., assignor to Bell Telephone Laboratories, Inc., New York, N. Y. Magnetic material. Sept. 19, 1927.
1,715,542	G. W. Elmen, Leonia, N. J., assignor to Bell Telephone Laboratories, Inc., New York, N. Y. Electrical coils and system employing such coils. Sept. 19, 1927.
1,715,543	G. W. Elmen, Leonia, N. J., assignor to Bell Telephone Laboratories, Inc., New York, N. Y. Magnetic core. June 20, 1928.
1,715,589	F. M. Boynton, Philadelphia, Pa. Rust-loosening composition. July 31, 1925.
1,715,599	C. T. Hixson, Aztec, N. Mex., assignor of one-fourth to W. W. Campbell, Aztec, N. Mex., and one-fourth to H. E. Pischel, Durango, Colo. Noncorrodible battery terminal. July 5, 1927.
1,715,620	J. E. Perry, Sharon, Pa., assignor to Valley Mould & Iron Corp., Hubbard, Ohio. Vertical ingot mold and stool. Sept. 29, 1927, division of original application filed Jan. 21, 1926.
1,715,646	G. W. Elmen, Leonia, N. J., assignor to Western Electric Co., New York, N. Y. Magnetic material and appliance. June 30, 1926, renewed Dec. 20, 1928.
1,715,647	G. W. Elmen, Leonia, N. J., assignor to Western Electric Co., New York, N. Y. Magnetic material. June 30, 1926.
1,715,648	G. W. Elmen, Leonia, N. J., assignor to Bell Telephone Laboratories, Inc., New York, N. Y. Magnetic material. June 28, 1928.
1,715,678	S. Schneider, Meissen, Germany, assignor to Westinghouse Electric & Manufacturing Co. Melting furnace. Sept. 13, 1926, in Germany, Dec. 14, 1925.
1,715,693	B. M. Bird, Seattle, Wash. Ore classifier. Feb. 25, 1927.
1,715,695	W. H. Cole, Paris, France. Derusting ferrous metals. Dec. 31, 1927, division of original application filed Sept. 20, 1927 and in Great Britain Aug. 22, 1927.
1,715,711	G. C. Kosian, Rockford, Ill., assignor to Rockford Malleable Iron Works, Rockford, Ill. Sand-blast apparatus. Jan. 11, 1923.
1,715,713	V. E. Legg, East Orange, N. J., assignor to Bell Telephone Laboratories, Inc., New York, N. Y. Treatment of magnetic materials. Sept. 1, 1928.
1,715,724	A. F. Thompson, Sunland, Calif. Pulverizer. June 13, 1927.
1,715,794	W. H. Sommer, Peoria, Ill. Machine for making welded reenforcing fabrics. June 30, 1927.
1,715,824	W. E. Duersten, Milwaukee, Wis., assignor by mesne assignments to Globar Corp., Niagara Falls, N. Y. Electrical resistance unit. Aug. 29, 1924.
1,715,867	B. D. Saklatwalla, Crafton, Pa., assignor to Vanadium Corporation of America, Bridgeville, Pa. Vanadium alloy. Feb. 2, 1928.
1,715,936	J. P. Madden, Bethlehem, Pa., assignor to Bethlehem Steel Co. Extrusion press. Aug. 25, 1925.
1,715,960	F. Tharaldsen, Christiania, Norway. Condenser for zinc vapors from electric furnaces. June 26, 1923, and in Norway Nov. 3, 1921.
1,715,969	E. G. Whelpley, Cleveland, Ohio, assignor to The Shea-Whelpley Construction Co., Cleveland, Ohio. Checkerwork construction. Mar. 9, 1928.
1,715,979	H. C. Bigge and C. R. Ellicott, Bethlehem, Pa., assignors to Bethlehem Steel Co. Low-carbon chromium steel. Nov. 15, 1924.
1,716,039	J. E. Fries, Birmington, Ala. Rolling mill. July 17, 1926.
1,716,040	A. L. Genter, Salt Lake City, Utah, assignor to Genter Thickener Co. Continuous-filter thickening apparatus. Oct. 16, 1925.
1,716,050	W. M. Grosvenor and V. P. Gershon, New York, N. Y. Manufacture of alloys. Feb. 3, 1925.
1,716,068	L. Lee, Youngstown, Ohio. Pickling machine. Jan. 15, 1925.
1,716,096	R. B. Weeks, Cleveland, Ohio, assignor by mesne assignments to The Wayne Pump Co., Baltimore, Md. Glare shield for electric welding. May 18, 1927.
1,716,104	E. K. Bolton, Wilmington, Del., assignor to E. I. du Pont de Nemours & Co., Wilmington, Del. Concentration of ores by flotation. May 22, 1926.
1,716,181	H. P. Parrock, Brookline, Mass. Manufacture of alloy pig iron. Dec. 24, 1926.
1,716,191	N. H. Schermer and C. G. Heilman, Highland Park, Mich. Method of treating metallic bodies on one surface. Oct. 24, 1927.
1,716,205	C. Bücher, Wiesbaden, Germany. Method of rendering iron pipes immune from the attack by water and apparatus for performance of this method. Feb. 3, 1927, in Germany Feb. 12, 1926.
1,716,228	J. Q. Horne, Lock Haven, Pa. Continuous-settling device. Sept. 7, 1926.
1,716,309	G. J. Fournier, Danville, Ill. Classifier. Oct. 3, 1927.
1,716,320	L. J. Pearson, Wyncote, Pa., assignor to Philadelphia Storage Battery Co., Philadelphia, Pa. Storage-battery plate and process of making same. May 22, 1920.
1,716,342	J. S. Haas and R. Bernhard, Allentown, Pa., assignors to Taylor Engineering and Manufacturing Co., Allentown, Pa. Gyratory crusher. Jan. 12, 1924.
Re 17,323	R. D. Davies, Huntington Park, Calif , assignor by mesne assignments to P. L. & M. Co. Process of facing the cutting edges of drilling tools. Oct. 1, 1928. (Original No. 1,613,942, filed May 24, 1926, issued Jan. 11, 1927.)
Re 17,325	W. A. Stuart, Cleveland, Ohio, assignor to Inland-Stuart Linings, Inc. Blast furnace. Jan. 10, 1929. (Original No. 1,632,633, filed Dec. 27, 1924, issued June 14, 1927, and Re 16,697 filed June 27, 1927, issued Aug. 9, 1927.)
1,716,362	P. Billigmann, Duisburg, Germany, assignor to Deutsche Maschinenfabrik Akt.-Ges., Duisburg, Germany. Straightening machine provided with rolls. Jan. 23, 1925, in Germany Feb. 2, 1924.
1,716,391	B. Talbot, Middlesbrough, England. Metallurgical furnace. Jan. 31, 1925, in Great Britain, Apr. 24, 1924.
1,716,395	L. J. Trostel, Baltimore, Md., assignor to General Refractories Co., Philadelphia, Pa. Process of making refractory composition and articles therefrom. June 7, 1926.
1,716,442	Le R. H. Hoffer, Brooklyn, N. Y., assignor to T. E. Murray, Brooklyn, N. Y. Electric welding machine. Apr. 10, 1924.
1,716,545	G. M. J. Mackay, Schenectady, N. Y., assignor to General Electric Co. Thermionic electrode. Mar. 6, 1926.
1,716,590	A. R. Lytle, Elmhurst, N. Y., assignor to Union Carbide & Carbon Research Laboratories, Inc. Nonferrous welding rod. Dec. 6, 1927.
1,716,599	W. M. Peirce and E. A. Anderson, Palmerton, Pa., assignors to The New Jersey Zinc Co., New York, N. Y. Mechanically worked zinc product. Feb. 9, 1928.
1,716,602	V. G. Ross, Seattle, Wash., assignor by mesne assignments to Continental Can Co., Inc., New York, N. Y. Method and means for separating metal sheets. Sept. 7, 1927.
1,716,614	S. R. Bergman, Nahant, Mass., assignor to General Electric Co. Electric welding. Aug. 4, 1925, renewed Oct. 6, 1927.
1,716,671	W. E. Taylor, East Orange, N. J., assignor to American Can Co., New York, N. Y. Agitated solder bath. Mar. 17, 1926.
1,716,695	F. J. Hinderliter, Tulsa, Okla. Bit forge. Feb. 23, 1927, renewed Aug. 23, 1928.
1,716,737	J. T. Ramsden, Philadelphia, Pa., assignor to The Tabor Manufacturing Co. Turntable molding machine. Feb. 16, 1926.
1,716,775	A. Hayes, Ames, Iowa. Optical pyrometer. Aug. 12, 1926.
1,716,792	A. L. Nelson, Detroit, Mich., assignor to Bohn Aluminum & Brass Corp., Detroit, Mich. Molding apparatus. June 15, 1925.
1,716,829	E. Musheiyko, Youngstown, Ohio. Means for operating pouring muzzle stoppers in molten-metal ladles. July 9, 1928.
1,716,833	C. H. Rich, Worcester, Mass., assignor to Riley Stoker Corp., Worcester, Mass. Method of casting. Mar. 6, 1926.
1,716,847	R. O. Berg, Detroit, Mich., assignor to Michigan Steel Tube Products Co., Detroit, Mich. Welding unit and method of welding. June 1, 1926.
1,716,943	R. S. Archer and W. L. Fink, Cleveland, Ohio, assignors to Aluminum Co. of America, Pittsburgh, Pa. Aluminum-beryllium alloy and method of treatment. Nov. 22, 1926.
1,716,956	W. M. Hepburn and E. W. Weaver, Toledo, Ohio, assignors to The Surface Combustion Co., Inc., Toledo, Ohio. Annealing furnace. Feb. 8, 1928.
1,717,107	T. J. Jamison, Homestead, Pa. Open-hearth furnace. Nov. 15, 1926.
1,717,109	J. Last, Wallington, England. Mold-aligning means. Jan. 7, 1927, in Great Britain Nov. 22, 1926.
1,717,119	J. T. Ramsden, Philadelphia, Pa., assignor to The Tabor Manufacturing Co. Molding machine. Jan. 3, 1928.
1,717,140	O. Brandenberger, Zürich, Switzerland, assignor to Zahner & Schiess & Co., St. Gall, Switzerland. Lead coating of articles. Aug. 17, 1927, in Germany Aug. 30, 1926.
1,717,153	C. T. Hennig, Cleveland, Ohio. Method of desulphurizing steel. Aug. 7, 1924.
1,717,160	F. O. Kichline, Lebanon, Pa., assignor to Bethlehem Steel Co. Reduction of complex ores. Dec. 4, 1924, renewed Mar. 3, 1927.
1,717,220	C. E. Jones, Schenectady, N. Y., assignor to General Electric Co. Treatment of small metal-coated parts.
1,717,245	W. C. Patterson, Ontario, Calif., assignor to Edison Electric Appliance Co., Chicago, Ill Molding machine. Nov. 14, 1927.
1,717,250	J. J. Phelan, Troy, N. Y., assignor to General Electric Co. Brazing flux. June 19, 1928.
1,717,254	J. Polak, Prague, Czechoslovakia. Casting machine. Aug. 8, 1928, in Czechoslovakia Sept. 1, 1927.
1,717,284	H. G. A. v. Kantzow, Hallstahammar, Sweden. Fire-resistant alloy with high electric resistance. Dec. 19, 1927, in Sweden Dec. 15, 1926.
1,717,325	D. J. Ryan, Cleveland, Ohio, assignor to The Cleveland Trust Co., Cleveland, Ohio. Method of and means for making reenforced cores of molds. Apr. 17, 1925.
1,717,342	A. Marland, Conshohocken, Pa., assignor to John Wood Manufacturing Co., Conshohocken, Pa. Manual holder for arc welding electrodes. Sept. 30, 1927.

Austrian Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
113,085	Guggenheim Brothers, New York, N. Y. Process for concentrating minerals by flotation. Dec. 15, 1928.
112,962	K. Mauler, Vienna, Austria. Method for the systematic and rapid determination of the absolute or relative degree of rust-resistance of iron, steel and iron alloys. Dec. 15, 1928.
113,022	Maschinenfabrik Winkler, Fallert & Co., Akt.-Ges., Bern, Switzerland. Drive for automatic casting machines, for opening and closing the mold and for controlling removal of castings. Dec. 15, 1928.
112,963	F. Bischitzky, Aussig, Czechoslovakia. Process for recovery of tin, lead, copper and zinc from alloys, mixtures, ores and residues. Dec. 15, 1928.
112,969	K. Becker, Dobrava pri Jesenicah, Jugoslavia. Method for joining the sections of electric furnace electrodes. Dec. 15, 1928.
113,156	Siemens-Schuckertwerke G. m. b. H., Berlin-Siemensstadt, Germany, assignee of K. W. Drescher, Berlin, Germany. Lathe-tool. June 15, 1928.
113,157	I. G. Farbenindustrie Akt.-Ges., Frankfurt a. M., Germany. Method of drawing shapes from strips of magnesium alloys. Aug. 15, 1928.
113,179	Bremer Silberwaren-fabrik Akt.-Ges., Sebaldbrück, near Bremen, Germany. Silver-plated tableware and process for making it. May 15, 1927.
112,943	"Elin" Akt.-Ges. für elektrische Industrie, Vienna, Austria. Welding-electrode holder and welding-electrode. Dec. 15, 1928.

British Patents

Specifications Open to Public Inspection in Great Britain

Patent No.	Patentee, Subject of Invention, and Filing Date *
310,489	Aciéries Réunies de Burbach-eich-Dudelange, Soc. Anon. Annealing-cases. Apr. 27, 1928.

---

* The filing date given for British patents is that claimed under the International Convention.

Patent No.	Patentee, Subject of Invention, and Filing Date
310,458	S. Westberg. Process of baking a highly refractory lining in metallurgical furnaces, especially induction furnaces. Apr. 26, 1928.
310,494	K. Thiel. Process and apparatus for rolling sheet metal, particularly sheet-metal tablets, sheet-metal bands, sheet-metal strips and the like. Apr. 27, 1928.
310,510	Soc. Anon. des Hauts-Fourneaux et Fonderies de Pont-a-Mousson. Sand-packing devices for pipe-molds. Apr. 27, 1928.
310,511	Soc. Anon. des Hauts-Fourneaux et Fonderies de Pont-a-Mousson. Pipe-casting machines. Apr. 27, 1928.
310,371	P. Girod. Casting of ingots of metals or alloys. Apr. 24, 1928.
310,520	O. Hering. Rolling device for the manufacture of iron and steel balls. Apr. 27, 1928.
310,468	P. Ries and F. Bicheroux. Process for desulphurizing iron in the converter, and means for carrying out said process. Apr. 26, 1928.
310,341	J. Mehl. Flux-coated electrodes for electric welding. Apr. 23, 1928.
310,342	Maschinenbau-anstalt Humboldt. Tube mills. Apr. 23, 1928.
310,425	I. G. Farbenindustrie Akt.-Ges. Process for the recovery of copper from spent copper lyes. Apr. 25, 1928.
310,427	J. Bauer. Chrome bath for producing especially white, soft and easily polished chromium deposits. Apr. 25, 1928.
310,834	F. Krupp Grusonwerk Akt.-Ges. Reaction vessel for froth-flotation processes. May 1, 1928.
310,837	Deutsche Gold-und Silber-Scheideanstalt, vorm. Roessler. Process for cementing and hardening iron, steel and the like. May 1, 1928.
310,876	F. Krupp Akt.-Ges. Process for producing bodies having a predominating percentage of tungsten or molybdenum. May 2, 1928.
310,962	H. André. Non-corrosive alloy. May 5, 1928.
310,812	Research Corporation. Process of surface-plating of metals with alloys. Apr. 30, 1928.
310,885	F. Krupp Akt.-Ges. Process for producing an alloy consisting of carbide of tungsten or molybdenum and of a lower melting metal or metalloid. May 2, 1928.
311,393	Annener Gussstahlwerke Akt.-Ges. Making of castings. May 12, 1928.
311,267	Deutsche Edelstahlwerke Akt.-Ges. Manufacture of alloys. May 8, 1928.
311,369	Zaklady Hohenego-Hohenlohe-Werke Spolka Akcyjna. Process for treating zinc-containing materials, especially roasted zinc ores, mixed zinc and lead oxides and the like. May 10, 1928.
311,269	E. Hickman y Emparan. Air alternators for use in connection with blast furnaces and the like. May 8, 1928.
311,239	Dr. J. Barnitzke. Flotation process for oxide ores. May 7, 1928.
311,337	Vereinigte Stahlwerke Akt.-Ges. Process for the manufacture of articles, particularly screws and rivets, by upsetting in the cold. May 9, 1928.
311,290	British Thomson-Houston Co., Ltd. Methods of working normally brittle sheet metal. May 8, 1928.
311,428	G. F. Royer. Apparatus for preparing molders' sand. May 12, 1928.
311,705	Vereinigte Glühlampen und Electricitäts Akt.-Ges. Process for the manufacture of oxide cathodes for discharge tubes. May 14, 1928.
311,766	M. Ow-Eschingen. Process of coating rubber articles with metal, particularly artificial sets of teeth or the like. May 16, 1928.
312,063	F. Krupp Akt.-Ges. Heating a metal melt within a ladle. May 18, 1928.
312,064	F. Krupp Akt.-Ges. Ladles. May 18, 1928.
312,066	R. Michel. Rolling mills. May 19, 1928.

British Patents

Complete Specifications Accepted

Patent No.	Patentee, Subject of Invention, and Filing Date
284,991	Vereinigte Stahlwerke Akt.-Ges. Process of gaining iron from iron-containing ores with the formation of ferric chloride. Feb. 7, 1927.
284,976	A. A. Frey. Manufacture of iron or alloys thereof. Feb. 5, 1927.
300,249	Barber Asphalt Co. Metallic alloy. Nov. 10, 1927.
303,490	L. Renault. Arc-welding electrode. Jan. 5, 1928.
299,701	R. Ardelt. Ramming machine for forming pipe molds. Oct. 29, 1927.
283,132	Chemische Fabrik Johannisthal Ges. and Dr. I. F. Trostler. Method for the recovery of copper and nickel. Jan. 4, 1927.
284,191	C. Rötzel and G. Krug. Process and apparatus for coating band iron with a rust-protective metal. Jan. 22, 1927.
285,373	I. G. Farbenindustrie Akt.-Ges. Manufacture of electrolytic zinc. Feb. 14, 1927.
285,038	Metallgesellschaft Akt.-Ges. Method of reciprocal action between gases and finely divided materials. Feb. 9, 1927.
288,319	Vereinigte Stahlwerke Akt.-Ges. Process for gaining iron from iron-containing ores with the formation of ferric chloride. (Addition to No. 284,991.) Apr. 7, 1927.
292,621	Metallgesellschaft Akt.-Ges. Roof, wall, or other surface covering of corrosion-proof metals or alloys, especially copper. June 23, 1927.
282,200	Vereinigte Stahlwerke Akt.-Ges. Process of annealing carbon-containing iron and steel. Jan. 8, 1927.
299,300	F. Krupp Grusonwerk Akt.-Ges. Processes for the recovery of volatilizable metal from iron-containing materials. Oct. 22, 1927.
299,850	A. M. Erichsen. Chill-mold for casting non-ferrous metals. Nov. 2, 1927.
305,453	Leipziger Schellpressenfabrik Akt.-Ges., formerly Schmiers, Werner & Stein. Method of producing points of adhesion for galvanic deposits on light metal bodies. Feb. 4, 1928.
310,432	J. Simmons & Sons, Ltd. and J. H. Pagdin. Method and means of packing or making up bundles or packages of steel plates or sheets, etc. Oct. 26, 1927.
310,383	I. G. Farbenindustrie Akt.-Ges. Manufacture and production of electrodes for Edison accumulators. Nov. 25, 1927.
310,386	C. R. Jernberg. Method of and apparatus for producing forgings. Jan. 18, 1928.
310,347	Cammell Laird & Co., Ltd., J. M. Allen and A. P. Hague. Surface-hardening of metallic bodies or articles by heat treatment and apparatus therefor. Jan. 23, 1928.
310,554	H. Kreill. Process of protecting wood and metal from corrosive influences. Jan. 25, 1928.
310,449	British Mannesmann Tube Co., Ltd., and R. F. Weiser. Internal lining or coating of hollow bodies such as tubes and the like. Jan. 26, 1928.
310,576	S. E. Saunders and G. Newman. Joining together of metal plates. Feb. 2, 1928.
310,639	H. L. Sulman and H. F. K. Picard. Recovery of tin from ores and the like. Apr. 14, 1928.
310,640	E. W. Terry. Antirust or anticorrosive preparation. Apr. 16, 1928.
310,663	Gesellschaft für Forderanglagen E. Heckel. Process for producing steel castings. May 3, 1928.
310,665	H. Stüting. Universal rolling mills. May 5, 1928.
310,696	J. Davies. Process of coating metallic surfaces for prevention of corrosion. June 7, 1928.
310,356	H. H. Alexander. Melting and refining of copper. Jan. 16, 1928.
310,761	A. O. Smith Corp. Still and method of making same by electric arc-welding. Dec. 24, 1927.
310,780	Metals Production, Ltd. Rotary furnaces and kilns. Jan. 30, 1928.
310,992	G. Brunhübner. Means and process for uniting metal, especially joints of chain, rings, etc. Feb. 3, 1928.
311,139	Wellman Seaver Rolling Mill Co., Ltd., and R. Hutchison. Apparatus for the manufacture of metal tubes and other tubular metal articles. June 30, 1928.
311,141	I. G. Farbenindustrie Akt.-Ges. Production of porous metal articles from metal powder. July 9, 1928.
311,256	T. R. Haglund. Iron and steel alloys. Feb. 7, 1928.
311,457	Testa Ges. Press for extruding or squirting metal tubes. Feb. 13, 1928.
311,585	R. Wilson. Core-making machine for use with foundry work and like purposes. June 29, 1928.
311,588	J. L. F. Vogel. Hardening of molybdenum iron or steels. July 4, 1928.
311,648	C. B. Pike. Method of and apparatus for removing patterns and castings from sand molds. Dec. 24, 1928.
311,677	Standard Telephones and Cables, Ltd. (Western Electric Co., Inc.) Composite magnetic materials. Feb. 11, 1928.
311,749	International Nickel Co. and E. J. Bothwell. Alloys. Feb. 15, 1928.
311,798	International Nickel Co., P. D. Merica, J. S. Vanick and T. H. Wickenden. Manufacture of cast iron. Feb. 15, 1928.
311,799	International Nickel Co. and N. B. Pilling. Alloys. Feb. 15, 1928.
311,909	S. C. Smith. Treatment of nickeliferous materials. Apr. 18, 1928.
311,946	W. R. Hume. Manufacture of sheet metal pipes and the like. May 21, 1928.
311,965	Società Alti Forni, Fondire, Acciairei e Ferriere Franchi Gregorini. Molds for centrifugal casting of metal tubes. June 16, 1928.
311,991	Cayzer Tin Smelting Co. (Proprietary), Ltd. Process of concentrating ores containing platinum and metals of the platinum group. July 24, 1928.
311,998	I. G. Farbenindustrie Akt.-Ges. Method of treating magnesium and its high percentage alloys in the molten state. Aug. 9, 1928.
312,006	Hevi Duty Electric Co. Electric resistance furnaces. May 22, 1928.
311,812	H. H. Alexander. Refining of copper. Jan. 16, 1928.
312,027	W. R. Hume. Manufacture of sheet metal pipe and the like. May 21, 1928.

Canadian Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
289,556	F. Dietzsch, Kingston-on-Thames, Surrey, England. Ore processing. Nov. 2, 1927.
289,601	H. J. van Royen, Hörde, Westfalen, Germany. Iron and steel manufacture. Feb. 20, 1928.
289,611	F. Wüst, Düsseldorf, Germany. Iron purification. June 22, 1927.
289,652	International Nickel Co., assignee of C. McKnight, Jr., Sewickley Pa. Steel alloy. Feb. 6, 1928.
289,669	The Paper & Textile Machinery Co., assignee of W. H. Millspaugh, both of Sandusky, Ohio. Centrifugal casting machine. Apr. 14, 1925.
289,699	L. Jones, Muncie, Ind., and R. E. Fitzsimmons, Youngstown, Ohio, assignee of one-half interest. Molten metal purifying apparatus. July 26, 1928.
289,702	C. J. Grist, Berkswell, Warwickshire, and C. W. St. J. Rowlandson, London, England, assignee of $^4/_5$ interest. Apparatus for processing rails, tools of steel alloys or iron. Jan. 5, 1928.
289,706	H. J. Hater, assignee of H. D. Rindsberg, both of Cincinnati, Ohio. Mold. Nov. 21, 1928.
289,715	G. G. Griswold, Jr., and G. E. Sheridan, both of Butte, Mont. Ore flotation. Mar. 9, 1928.
289,729	T. E. Catherwood, Hagersville, Ont. Welding shield. Jan. 29, 1929.
289,732	W. J. Cook, Wheeling, W. Va. Pickling apparatus. Aug. 22, 1928.
289,733	W. J. Cook, Wheeling, W. Va. Pickling apparatus. Aug. 22, 1928.
289,758	H. S. MacKay, London, England. Copper and zinc extraction method. Jan. 30, 1926.
289,767	A. Pacz, East Cleveland, Ohio. Coating for metal. May 28, 1927.
289,801	Robert Bosch Akt.-Ges., Stuttgart, assignee of F. Ehrmann, Stuttgart-Feuerbach, Germany. Casting apparatus. June 28, 1927.
289,822	Det Norske Aktieselskab for Elektrokemisk Industri, Oslo, Norway, assignee of M. O. Sem, Buffalo, N. Y. and C. W. Söderberg, Oslo, Norway. Electrode manufacture. Sept. 1, 1927.
289,837	The International Nickel Co., New York, N. Y., assignee of T. H. Wickenden, Roselle, N. J., and P. D. Merica, New York, N. Y. Addition material for ferrous metals. Jan. 7, 1925.
289,838	The International Nickel Co., New York, N. Y., assignee of T. H. Wickenden, Roselle, N. J., and P. D. Merica, New York, N. Y. Addition material for ferrous metals. Apr. 13, 1926.
289,863	The Western Electric Co., Inc., New York, N. Y., assignee of J. H. White, Cranford, N. J. Metallurgical process. (Addition of vanadium to nickel.) June 1, 1927.
289,905	W. P. Dreaper, Hampstead Heath, County of London, England. Gold and platinum alloy. May 30, 1928.
289,950	R. Rodrian, New York, N. Y. Metal recovery. Sept. 17, 1926.

Patent No.	Patentee, Subject of Invention, and Filing Date
290,027	The A. O. Smith Corp., assignee of C. B. Langstroth, both of Milwaukee, Wis. Oil refining still and method of making the same by electric welding. Jan. 9, 1928.
290,028	The A. O. Smith Corp., Milwaukee, Wis., assignee of W. F. Woolard, Wauwatosa, Wis. Oil refining still and method of making the same by electric arc welding. Jan. 9, 1928.
290,037	The Valley Mould and Iron Corporation, Hubbard, Ohio, assignee of W. H. Ramaga, Girard, Ohio. Ingot mold set-up. Mar. 20, 1928.
290,064	R. B. Hannock, Gary, Ind. Bar-annealing apparatus. Mar. 28, 1928.
290,069	H. M. Sutton, W. L, Steele and E. G. Steele, Dallas, Texas. Material separation. Oct. 24, 1927.
290,110	E. Jahn, Arnswalde, Germany. Solid separator. Oct. 16, 1928.
290,125	F. C. McConville, Princeton, B. C. Ore classifier. June 5, 1928.
290,148	Aktiebolaget Svenska Kullagerfabriekn Hofors Bruk, assignee of L. Nordenfelt, both of Hofors, Sweden. Art of manufacturing hollow rods. June 28, 1928.
290,157	The Canadian General Electric Co., Ltd., Toronto, Ont., assignee of G. R. Shaw, South Euclid, Ohio, and B. F. Telkamp, Cleveland Heights, Ohio. Filament processing. May 11, 1928.
290,188	The International Nickel Co., Inc., assignee of The International Nickel Co., New York, N. Y., assignee of E. J. Bothwell, West New Brighton, N. Y. Nickel and copper composition. Nov. 28, 1927.
290,189	The International Nickel Co., Inc., assignee of The International Nickel Co., New York, N. Y., assignee of W. A. Mudge, Huntingdon, W. Va. Manufacture of alloys of copper, nickel and aluminum. Feb. 20, 1926.
290,190	The International Nickel Co., New York, N. Y., assignee of W. A. Mudge, Huntingdon, W. Va. Manufacture of alloys of copper, nickel and aluminum. Jan. 16, 1929.

French Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
662,487	B. Granigg. Process for the mechanical separation of materials having different electrical or magnetic properties. Oct. 18, 1928.
662,120	W. S. Smith, H. J. Garnett and J. A. Holden. New magnetic alloys and process for making them. Apr. 30, 1928.
662,146	I. G. Farbenindustrie Akt.-Ges. Method of casting magnesium and magnesium alloys. Feb. 3, 1928.
662,257	J. J. A. Commenges Mercié. Process for making tungsten filaments. Feb. 3, 1928.
662,291	Société d'électrochemie, d'électrometallurgie et des Aciéries Electriques d'Ugine. Process for the simultaneous production of refined aluminum-silicon auxiliary alloys and alloys suitable for metallurgical and chemical applications. Feb. 8, 1928.
662,292	L. D. J. Tisseyre. Electric furnace installation for the heat treatment of tools and small objects. Feb. 8, 1928.
662,401	Balz Erzrostung G. m. b. H. Process and apparatus for introducing air into the roasting chambers of mechanical muffle roasting furnaces. Oct. 16, 1928.
662,445	H. J. Schiffler. Process for making low-alloy steels, unaffected by oxidation up to 800° C. Oct. 17, 1928.
662,489	Aluminium Werke Ak. Process for producing aluminum by fusion electrolysis. Oct. 18, 1928.
662,541	Gewerkschaft Wallram. Wire-drawing method. Oct. 19, 1928.
662,300	Société Génerale d'Applications Electro-Thermiques. Electric induction furnace. Feb. 8, 1928.
662,272	Société La Radiotechnique. New process for treating tungsten. Feb. 6, 1928.
662,222	Société d'Exploitation de Munition. Process for briquetting pulverized ore. Feb. 1, 1928.
662,283	J. Bronn. Refractory material containing chromite and process for its preparation. Feb. 7, 1928.
662,673	A. Messer. Machine for cutting with the blow-pipe. Oct. 5, 1928.
662,824	C. R. Nichols and S. H. Williston. Electric prospecting method. Oct. 23, 1928.
662,615	Berzelius Metallhütten G. m. b. H. Process for the electrolytic refining of impure metals and alloys. May 21, 1927.
662,653	S. I. Lévy and G. W. Gray. Improvements in the treatment of pyrites or other sulfide ores or materials containing iron. Sept. 6, 1928.
662,684	Witkowitzer Bergbau und Eisenhütten Gewerkschaft, and A. Andziol. Mechanical shaft furnace for roasting, heating, sintering, etc., of ores and other finely divided materials. Oct. 9, 1928.
662,685	R. H. V. Christensen. Process and apparatus for casting metal under pressure. Oct. 9, 1928.
662,691	Societe Alti Fornie, Fonderie, Acciaierie e Ferriere Franchi Gregorini. Continuous casting machine. Oct. 11, 1928.
662,696	J. B. Read and M. F. Coolbaugh. Process for roasting ore containing sulfur. Oct. 12, 1928.
662,726	A. C. Spark Plug Co. Alloy for spark plug electrodes. Oct. 20, 1928.
662,642	J. H. St. H. Mawdsley. Improvements in the production of electric current to be used for electric welding. Aug. 16, 1928.
662,742	Chemisches Werk Zürich A. G. Process and apparatus for pickling metal objects. Oct. 22, 1928.

German Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
476,857	W. E. Watkins, New York, N. Y. Method of treating rolled sheets by pickling and annealing. Aug. 3, 1926, in the United States. June 16, 1926.
476,452	Fried. Krupp Grusonwerk, A. G., Magdeburg-Buckau, Germany. Hydraulic extrusion press for metals, with continuously running compression pump. Feb. 20, 1926.
476,397	K. Helmholz, Essen, Germany. Process for breaking down chromite. Nov. 26, 1926.
476,513	S. Westberg, Oslo, Norway. Method of heat-treating metals and alloys in an atmosphere of hydrogen, especially applicable to iron and steel in the form of plates, sheets, strips, wires, etc. Apr. 30, 1926.
476,410	Patent-Treuhand-Gesellschaft für elektrische Glühlampen m. b. H., Berlin, Germany. Sintered contact points of refractory metal, especially tungsten, for electric circuit breakers. Mar. 1, 1927.
476,414	K. Grocholl, Kronach, Bavaria, Germany. Method of operating cupola furnaces. May 17, 1928.
476,384	Metallgesellschaft A. G., Frankfurt a. M., Germany. Aluminum-silicon casting alloy. Nov. 27, 1921, in the United States Nov. 27, 1920.
476,619	Norddeutsche Affinerie, Hamburg, Germany. Process for refining antimony electrolytically. July 19, 1927.
476,431	Hahn and Kolb, Stuttgart, and E. Haas, Gotha, Thüringia, Germany. Cleaning apparatus, especially for metal parts. May 9, 1928.
476,366	A. W. F. Schammer (neé Stolle) and A. H. Schammer-Uhlendorf, Dresden, Germany. Apparatus for de-greasing and cleaning materials and objects of any kind, especially hollow bodies. (Addition to No. 456,811.) Dec. 17, 1926.
476,367	Heraeus-Vacuumschmelze A. G., and W. Rohn, Hanau a. M., Germany. Piercing metal ingots having a high yield point, by the Ehrhardt process. Sept. 2, 1926.
476,369	W. C. Heraeus G. m. b. H., Hanau a. M., Germany. Joining metal parts, especially sheets of precious metals, by soldering or welding. Mar. 4, 1928.
476,480	W. Richter, Mannheim, Germany. Production of a rigid union between pieces of tool steel and their holders by a welding or soldering process. Feb. 7, 1925.
476,481	Osnabrücken Kupfer u. Drahtwerk, Osnabrück, Germany. Copper-aluminum alloy for welding aluminum bronze. Jan. 1, 1927.
476,790	W. Klein, Hagen i. W., Germany. Charging apparatus for dewatering centrifuges. Nov. 28, 1925.
476,894	Eumoco Akt.-Ges. für Maschinenbau, Schlebusch-Manfort, Germany. Lead-cable press. Nov. 10, 1926.
476,910	Hochofenwerk Lübeck Akt.-Ges., Herrenwyk, near Lübeck, Germany. Packing for the bells of blast-furnace tops. Nov. 1, 1928.
476,841	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. Means for determining and indicating the level of the charge in blast furnaces and the like. Dec. 15, 1925.
476,858	E.-G. Köhler, Andernach, Germany. Device for sealing a tunnel muffle furnace for strip metal. June 16, 1926.
477,067	Meier and Weichelt Eisen-u.-Stahlwerke, Leipzig-Lindenau, Germany. Flaskless molding machine with stripping device operated by compressed air. (Addition to No. 379,439.) Oct. 9, 1925.
476,994	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. Apparatus for the simultaneous molding of several castings. Feb. 9, 1927.
476,812	L. Szilard, Berlin-Dahlem, Germany. Method of pouring metals into molds, using electric currents. Jan. 20, 1926.
476,814	The International Nickel Co., New York, N. Y. Removal of sulfur from nickel or crude copper-nickel matte. July 7, 1921.
476,962	Metallgesellschaft A. G., Frankfurt a. M., Germany. Brass alloy. Aug. 20, 1924.
476,965	E. Stirnemann, Gränichen, and A. Perret, Zürich, Switzerland. Aluminum solder. Nov. 20, 1925.
477,317	Herkules-Werk G. m. b. H. (formerly Wilh. Momma), Wetzler, Germany. Sheet-bending machine with two stationary rolls and one movable roll. Oct. 14, 1928.
477,228	M. J. Lockner, Dortmund, Germany. Burner-head for regenerative furnaces. Mar. 8, 1927.
477,178	H. J. Grünewald, Hilchenbach, Germany. Annealing furnace for bright-annealing, in which the carrier for the material being annealed is connected with the cover. (Addition to No. 454,609.) Feb. 17, 1926.
477,187	Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. Induction furnace. Nov. 13, 1925.
477,334	Siemens-Planiawerke Akt.-Ges. für Kohlefabrikate, Berlin-Lichtenberg, Germany. Method of making large electrodes. June 12, 1925.
477,335	Demag Akt.-Ges., Duisburg, Germany. Vertically movable electrode holder for electric melting furnaces. Jan. 22, 1926.
477,397	Vereinigte Schmirgel- und Maschinen Fabriken Akt.-Ges., formerly S. Oppenheimer & Co., and Schlesinger & Co., Hannover-Hainholz, Germany. Molding machine with two telescoping pistons for the production of flaskless molds. (Addition to No. 343,478.) Apr. 14, 1928.
477,287	C. O. J. Bröms, Guldsmedshyttan, Sweden. Method of making combination castings, especially rolls with high surface hardness. Jan. 26, 1928, in Sweden Jan. 29, 1927.
477,379	Hüttenwerke Tempelhof A. Meyer, Berlin-Tempelhof, Germany. Method of producing mixed tin from lead-tin alloys. Oct. 12, 1924.
477,290	The Rhodesia Broken Hill Development Co., Ltd., London, England, and Broken Hill, North Rhodesia. Technological removal of nickel from zinc sulfate solution. Sept. 9, 1926.
477,132	H. Baecker, Remscheid, Germany. Method of and apparatus for pickling strip iron, strip steel and the like. Aug. 10, 1927.
477,569	Magnet-werk G. m. b. H. Eisenach, Spezialfabrik für Elektromagnetapparate, Eisenach, Germany. Magnetic drum separator. April 11, 1926.
477,657	T. Franz, Bochum, Germany. Method of and apparatus for preparation of slimes. Oct. 1, 1924.
477,441	F. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany. Device for charging annealing furnaces. Mar. 10, 1926.
477,585	H. Emmermann, Hannover, Germany. Molding machine. May 1, 1927.
477,586	Gelsenkirchener Bergswerk Akt.-Ges., Abteilung Schalke, Gelsenkirchen, Germany. Support for the pouring trough of centrifugal casting molds. Oct. 7, 1926.
477,457	A. Roitzheim and W. Remy, Berlin-Oberschöneweide, Germany. Furnace and process for smelting zinc ores and other zinciferous materials in continuously operating vertical reduction chambers. Nov. 14, 1925.
477,458	F. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany. Separate recovery of lead and zinc from oxide ores, smelter products and residues. (Addition to No. 473,016.) Aug. 9, 1925.
477,425	Aluminium Industrie Akt.-Ges., Neuhausen, Switzerland. Method of electrolytically recovering pure aluminum from crude aluminum, alloys and other aluminiferous material. Jan. 28, 1926.
477,500	Aluminium Industrie Akt.-Ges., Neuhausen, Switzerland. Method of electrolytically recovering pure aluminum from crude aluminum, alloys, etc. June 8, 1926.
477,597	Kollmar und Jourdan Akt.-Ges., Uhrkettenfabrik, Pforzheim, Germany. Method of annealing galvanized ornamental and other wares. July 26, 1927.

Italian Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
260,228	Electro Metallurgical Co., New York, N. Y. Zirconium-manganese steel. June 23, 1927.
260,258	A. Geyer, Paris, France. Improvements to processes for producing aluminum alloys. July 1, 1927, in France Feb. 4, 1927.
260,056	Kabushiki Kaisha Nihon Seikosho, Tokyo, Japan. System of heat-treating steel. Apr. 30, 1927, in Japan June 22, 1926.
260,199	O. Kröning, Hannover, and R. Boês, Harber, Hannover, Germany. Process for heat treating steel. June 15, 1927.
260,483	H. E. Sundberg, Stockholm, Sweden. Process for the electrolytic deposition of metals. July 23, 1927.
260,197	Argenteria Wellner Societa Anonimà Italiana, Florence, Italy. Process for the electrolytic deposition of metals. June 14, 1927.
260,168	Bánska a Kutni spolecnost, Brno; and A. Karner, Novy Bohumin, Czechoslovakia. System for drawing wires, etc., of unlimited length. June 2, 1926, in Czechoslovakia Oct. 1, 1926.
260,000	H. Hentschel and H. Gregersen, Hamburg, Germany. Blow-pipe for the autogenous cutting of rivet holes. Apr. 12, 1927.
260,047	A. Pacz, Cleveland, Ohio. Process for coating and coloring metals. June 30, 1927.
260,065	J. Polak, Prague, Czechoslovakia. Casting machine. May 23, 1927.
260,548	B. Racheeff and M. Gofmann, Paris, France. Chemical process for joining metals and its application. July 15, 1927, in France July 15, 1926.
260,350	A. Schwarz, Berlin, Germany. Process for working up mixtures of white metal and red metal wastes. May 5, 1927, in Austria May 5, 1926. (By Internationale Metall Akt.-Ges.)
260,091	Expanded Metal Co., Ltd., Westminster, London, England. Improved process for coating, impregnating or alloying metals or other materials with aluminum or aluminum alloys. Feb. 25, 1927, in Great Britain Dec. 14, 1926. (Addition to No. 257,564.)
260,329	Elektriske Industriovner A. S., Oslo, Norway. Electric heating element. July 7, 1927, in Norway Sept. 23, 1926.
260,517	Elektriske Industriovner A. S., Oslo, Norway. Improvements in the arrangement of heating elements in electric furnaces. July 7, 1927, in Norway Oct. 30, 1926.
260,518	Elektriske Industriovner, A. S., Oslo, Norway. Improvements in the arrangement of electric resistance furnaces. July 7, 1927, in Norway Oct. 30, 1926.
260,304	I. Rennerfelt, Torgärdsvärgen, Sweden. Device for the electrical production of heat. July 2, 1927, in Sweden July 3, 1926.
260,319	Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. Furnace or apparatus for heating by high-frequency induction. July 12, 1927, in Germany July 24, 1926.
260,352	Siemens-Schuckertwerke G. m. b. H., Berlin-Siemensstadt, Germany. Supporting block of refractory material for heating resistances. May 5, 1927, in Germany May 5, 1926.
260,534	R. Appel, Berlin, Germany. Process for the electrolytic separation of chromium for producing platings of chromium on other metals. July 21, 1927, in Germany July 21, 1926.

Norwegian Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
46,317	Siemens-Elektrowärme Gesellschaft m. b. H., Sörnewitz, near Meissen, Germany. Electric annealing furnace. Apr. 5, 1927.
46,322	B. Jirotka, Berlin, Germany. Process for producing metallic coatings on objects of aluminum or aluminum alloys. Jan. 20, 1926, in Belgium Jan. 22, 1925.
46,378	Automatic and Electric Furnaces, Ltd., and L. W. Wild, London, England. Electric furnace construction. June 15, 1928.
46,380	New Process Multi-Casting Co., New York, N. Y. Method of making sand molds in divided flasks. Feb. 10, 1926.
46,381	New Process Multi-Casting Co., New York, N. Y. Molding machine. Feb. 11, 1926, in the United States Nov. 3, 1925.
46,383	A. C. Jessup, Paris, France. Electrolytic process for producing magnesium and alkaline earth metals, as, for example, calcium. July 20, 1926.
46,384	A. C. Jessup, Paris, France. Process for the electrolytic production of light metals, as, for example, magnesium and calcium, by electrolysis of fused chlorides and apparatus for working this process. July 20, 1926.
46,405	N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands. Process for making oxide cathodes. Oct. 31, 1925, in the Netherlands Dec. 24, and Dec. 27, 1924.
46,406	N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands. Process for making oxide cathodes. Feb. 18, 1927, in the Netherlands Apr. 6, 1926.
46,412	P. E. Frøland, Høyanger, Norway. Construction of furnace for producing aluminum. Mar. 12, 1927.

Swedish Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
66,801	Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. Furnace with movable and tiltable hearth. June 16, 1927, in the United States June 23, 1926.
66,832	Eisen u. Stahlwerk Hoesch Akt.-Ges., Dortmund, Germany, assignee of F. Jordan. Method of plating sheet metal. Oct. 21, 1927.
66,845	M. Roeckner, Mülheim a. Ruhr, Germany. Method of rolling tubing from hollow ingots. Feb. 2, 1928, in Germany Feb. 25, 1927.
66,849	The Norwegian Electric Smelting Co., Ltd., Bradford, England, assignee of G. J. Stock. Electric arc furnace. (Addition to No. 49,207.) Apr. 24, 1925.
66,850	Aktiebolaget Ferrolegeringar, Stockholm, Sweden, assignee of B. M. S. Kalling, O. G. S. Anderson and S. D. Danieli. Method of melting metals or metallic alloys. Feb. 14, 1923.
66,851	W. Mathesius, Berlin-Charlottenburg, Germany. Iron alloy. Oct. 4, 1924.
66,852	S. Westberg, Oslo, Norway. Process for refining and heat-treating metals and alloys. Apr. 28, 1926.
66,856	W. S. Smith, Newton Poppleford, Devonshire; and H. J. Garnett, Sevenoaks, Kent, England. Magnetic alloy. May 2, 1927, in Great Britain July 27, 1926.
66,866	Aluminum Company of America, Pittsburgh, Pa., assignee of W. Hoopes, F. C. Frary and J. D. Edwards. Process for refining aluminum. Dec. 20, 1923, in the United States Dec. 21, 1922.
66,916	T. W. S. Hutchins, Davenham, England. Process for the electrical deposition of metals. (Addition to No. 63,235.) Aug. 30, 1924, in Great Britain Mar. 4, 1924.

New Patent Manager for Westinghouse

O. H. Eschholz has been appointed manager of the Patent Department of the Westinghouse Electric and Manufacturing Company, succeeding O. S. Schairer, who resigned to accept a similar position with the Radio Corporation of America. Mr. Eschholz's headquarters will be at the company's East Pittsburgh works.

Born at Holyoke, Mass., February 26, 1889, Mr. Eschholz was graduated in 1907 from the Springfield, Mass., Technical High School, and in 1910 from Worcester Polytechnic Institute, receiving his Bachelor of Science degree in Electrical Engineering. He studied law at the Duquesne University Law School, Pittsburgh, Pa.

In 1910, Mr. Eschholz entered the employ of the Westinghouse Company. In the next dozen years, he was engaged in engineering activity in many branches of the electrical art. Some 50 patents, a number of them of substantial importance, have been issued as a result of this work. The inertaire transformer was one of these inventions. Others had to do with circuit breakers, dynamo machines, radio, vacuum devices and electric welding.

Mr. Eschholz has a wide reputation in electric arc welding. During the war he participated in the work of the welding committee of the Emergency Fleet Corporation, which initiated the all-welded ship and was credited with doubling the effective cruising hours of the Allied destroyers.

In 1923 Eschholz took an executive position with a chemical company, later becoming production engineer for the Standard Gauge Steel Company, of Beaver Falls, Pa. He returned to the Westinghouse Company in April, 1924, and began work in the Patent Department. Since then he has participated in substantially every phase of patent work, devoting much of his time to the stimulation of research and invention on new and desirable lines.

(*Continued from page 22*)

for life is the ability to withstand repeated stresses of relatively high magnitude.

With alloys of aluminum, it then appears that the whole endurance stress-cycle curve must be considered, not only because the existence of an actual endurance limit is doubtful, but because the curves for two different alloys may cross and conclusions as to which alloy is the better for a given service may depend on the magnitude of the occasional high stresses that may be met.

From Jeffries' comments and Johnson and Oberg's data, it is evident that each heat-treated aluminum alloy must be separately studied, since the behavior of silicon in one of these cases would not have been predicted from the other.

Johnson and Oberg find it necessary to use a dozen specimens to get a reliable average for plotting a single point on the endurance curve. With it still a debatable question after tests to 500,000,000 cycles whether there is a true endurance limit for these aluminum alloys, we nominate Job for a job in the endurance testing laboratory dealing with these alloys. Air-driven, high speed fatigue testing machines are under development at the Bureau of Standards in this country and at the National Physical Laboratory in England, and it is evident that we must look to these for the ultimate answer. However, the question whether there is a "speed effect" must first be answered before we can utilize the high speed data.

The irritating thing in the study of the speed effect is that each lot of duralumin appears to have its own particular endurance properties, two lots of the same static properties showing some difference in endurance. Hence, one cannot take the slow-speed data from the literature, but must determine it on the same lot as the high-speed. The high-speed machines only handle sheet specimens, so the only slow speed machines that will serve for the comparison are flexural machines, not those for rotary bending, and the flexural machines have to operate at relatively very slow speeds to allow reliable stress measurements.

Thus, it is likely that the question of the actual existence of a true endurance limit for these alloys may remain as a source for argument even unto the next generation.

H. W. GILLETT

"High Spots" of the 32nd Annual Meeting of the American Society for Testing Materials

Henry S. Rawdon*

IN MANY respects, the thirty-second annual meeting of the American Society for Testing Materials held during the last week in June was one of the most successful ever held by this society. The combination of ideal seashore weather and a large attendance (over 1200) added to the well balanced interesting program helped to make it so. Two sessions were held simultaneously during each period, the one dealing with metallic materials, the other, with non-metallics such as cement, rubber, timber, stone and the like. This brief résumé relates to only the outstanding features of that part of the program dealing with metals.

In the election of the new President for the coming year, the "metals" were honored by the choice of T. D. Lynch, Research Engineer of Westinghouse Company.

Likewise the award of the Dudley medal for the best paper presented at the 1928 meeting to Messrs. Kanter and Spring for their work on the flow of metals when maintained for long periods at high temperatures is evidence of the high class work which is being done in the Society in the field of metals.

Standardization

Quite appropriately, the address of the retiring president, G. W. Thompson (Chief Chemist, National Lead Company) related to the primary object of the society—standardization. In developing his subject, "Standardization and Goodwill," Dr. Thompson emphasized that commercial products must be standardized to meet the demands of the consumer with the limitation, however, that this shall not go so far as to prevent obtainment of materials by the consumer which are best suited to his needs. The postulate may be laid down that both consumer and producer owes a duty to each other. Neither group can unreasonably resist the demands of the other. Producers must acquiesce in the reasonable demands of consumers for standard specifications and likewise consumers cannot rightfully insist upon standard specifications which would force producers to acquiesce in them before they are fully properly developed. The fact that standard specifications are often, if not usually, compromises is not a sound basis for criticism against them. Standard specifications are not fixed things, they are constantly subject to change. They should not be adopted prematurely, however, nor should they be amended prematurely. Constant growth is the ideal condition.

New Committee Activities

As is well known, by far the greater part of the work of the Society is accomplished by means of committees, the reports of which constitute a very considerable part of the program. While no review of the committee reports will be given here, it is of some interest to note some of the special committee activities during the year. Committee B-2, one of the oldest of the metal committees dealing with non-ferrous alloys and metals has become so large as to be unwieldy and cumbersome. It has been reorganized and several new and smaller ones formed from it dealing respectively with copper and copper alloys, light metals and alloys (aluminum and magnesium) and the combined field of tin, lead, zinc and antimony. The mother committee still remains although with a much narrower field. Very considerable attention is being given to the study of die casting alloys, their properties and permanence under varied service conditions. Test data from over 20,000 specimens are already available and are being studied by statistical methods. Further studies will include the determination under weather-exposure conditions of both of the two general types of these alloys—zinc-base and aluminum-base alloys.

Another new committee is the one organized to study the "corrosion resistant" alloys, that is, the iron-chromium, iron-nickel-chromium and similar alloys.

Special mention should be made of the excellent set of micrographs of α-brass presented as part of the Report of Committee E-4, "Metallography." These micrographs constitute a very valuable set of grain-size standards with grain size ranging from .010 mm. average grain diameter to .200 mm. average grain diameter.

Yielding of Metals under Stress

A subject which can always be depended upon to arouse lively discussion is that of the yielding of metals under stress. This meeting was no exception. In a discussion of the determination and significance of the proportional limit of metals, R. L. Templin presented data which led him to the conclusion that the so-called yield point is of considerably more importance than the proportional limit due to the smaller errors involved in its determination and that it is more easily determined on a routine commercial testing basis. The belief was expressed that the yield point is in all probability fully adequate for the needs of the designer and for product specifications. This view was upheld in the lively discussion which followed, the point being emphasized by H. F. Moore, however, that a more precise method of expressing just what is meant by the term is desirable. For steels, he suggested such methods of designations as, YP (drop) YP (e), "e" being the specified strain to correspond to the beginning of the relatively horizontal (constant load) portion of the stress-strain curve following the drop of beam. For metals which do not show a "drop of beam" a method of designation depending upon the set "q" produced upon release of the load, e. g., YP (q = .2%) = 50,000 lb./in.^{2}

Properties of Cast Iron

One of the most helpful of the technical sessions was the symposium on the physical properties of cast iron. The different papers have been bound together into one pamphlet, thus constituting a convenient reference book on the subject which should prove very useful. One idea emphasized throughout the symposium is that "gray iron is not an alloy but a series of alloys" the properties of which are determined according to the composition and treatment.

---

* Chief, Division of Metallurgy, Bureau of Standards

Cohesive Properties of Metals

Students of atomic physics and of the "new" metallography as extended by means of X-ray methods will await with interest the appearance in printed form of the masterly address presented by Dr. Saul Dushman on "The Nature of Cohesive Forces in Metals," the annual Marburg lecture. The speaker did not attempt to explain why a metal, such as copper, possesses strength but rather to explain in the language of atomic physics the correlation of the strength properties with the characteristics of the material as dependent upon its ultimate structural features.

Corrosion Activities

The American Society for Testing Materials is rapidly becoming the most active technical body engaged in the study of corrosion phenomena and corrosion testing methods. The pioneer work of Committee A-5 in studying, in an impartial manner by long-time extensive field tests, the effect of additions of small amounts of copper upon the corrosion-resistance of steel and iron has long been outstanding in the corrosion field. Although these tests have not yet been fully completed, their story is practically finished.

The results of a statistical study of the test data was presented to the Society by Messrs. Kendall and Taylerson and on the basis of these results it was reported that phosphorus in steel in combination with copper is also decidedly beneficial from the standpoint of atmospheric corrosion. In underwater corrosion, copper and other elements appear to have no marked effect. The exposure tests of galvanized sheets have now progressed far enough (2 years) so that definite conclusions are apparently warranted in the case of lightly coated sheet in corrosive atmospheres such as in Pittsburgh. It was reported that the full test of galvanized products (wire and fencing as well as miscellaneous hardware) will be in full swing before this summer closes.

Committee B-3 has in preparation three rather extensive series of exposure tests, the aim being to develop a satisfactory accelerated laboratory corrosion for the particular types of service studied, by correlation of the results obtained in the various exposure tests of a series of typical metals with the results of laboratory studies on the same metal. Twenty-four widely varying materials have been chosen and the exposures consist of atmospheric exposure in various locations, "plant" tests utilizing various chemical processes (pickling and other acid solutions and the like) and studies of "galvanic" acceleration of the corrosion of the metals.

As previously noted, determination of the corrosion behavior of the various types of die-casting alloys forms an important project which Committee B-2 is fostering. Mention has also been made of the newly organized committee to study the rapidly widening field of the "corrosion resistant" alloys. A corrosion project on a rather limited scale, but on a subject of intense practical interest, is that on the behavior of screen wire cloth which has been under way for a number of years—the work of Committee D-14.

At the meeting, the cooperation of the corrosion committees was solicited by the Electroplaters Society in carrying out the exposure test of electroplated metals, especially chromium plated, which have been planned as a part of the research program which the Electroplaters Society is backing.

Stress Corrosion Phenomena

Supplementing the work of previous years on this general subject, McAdam presented further data on the effect of cyclic stress accompanying corrosion in the case of ordinary steels, duralumin, Monel metal and stainless iron. The retarding or prevention of the stress-corrosion effect by the use of suitable inhibitors was clearly demonstrated by Speller and his associates. It was also clearly shown that the chloride concentration of the water is intimately related to the length of life under stress-corrosion conditions, as well as to the efficacy of any inhibitor-treatment of the water. By means of tension tests after corrosion of specimens corroded while under stress, Rawdon presented data showing the pronounced effect of stress-corrosion upon plain duralumin. By protecting the surface with a "skin" of aluminum, however, as in the case of the commercial material "Alclad duralumin" the stress-corrosion effect can for all practical purposes be entirely eliminated unless the stress condition is very severe.

Fatigue Studies

The endurance or "fatigue-properties" of metals received somewhat less attention than usual. A somewhat novel discussion of this subject was that presented by Peterson which dealt with tests carried out on *large* specimens by the rotating cantilever type of test. Data were presented by J. B. Johnson and T. T. Oberg which were interpreted as showing that, whereas the endurance limit of various aluminum alloys had previously been assumed on the basis of 300,000,000 cycles of stress, 500,000,000 are insufficient to establish the endurance limit with certainty. It was questioned in the discussion, however, whether sufficient care was taken in these tests, the carrying out of which requires *very* long periods of time, to ensure absolute freedom of corrosive attack of the metal during the progress of the test. Results were also presented (Townsend and Greenall) of endurance tests of non-ferrous sheet metals. It was concluded that the endurance limit for the brasses and other alloys studied varied approximately from 12 to 36 percent of their ultimate tensile strength whereas the commonly accepted ratio in the case of ordinary steels is about 40 percent of the tensile strength.

Miscellaneous

A paper on a subject somewhat out of the ordinary was one dealing with the wear resistance of bearing bronzes (French and Staples) some of which contained zinc as an added constituent. According to the laboratory tests, which still remain to be confirmed by service, the presence of as much as 4 percent of zinc is not detrimental to the use of the bronze for bearing purposes.

National Metals Congress

AMERICA'S first annual Metals Congress, an assemblage of the leaders in the metals industries and those who will be the leaders is to be held in Cleveland, Ohio, September 9th to 13th.

Here will be met for the first time the men who are responsible for the progress of this country in production, treatment, fabrication and use of the various metals, ferrous and non-ferrous.

Here, too, will be made reports on progress made during the year in the field of research and interesting and highly valuable papers will be read at the various sessions.

This National Metals Congress is, to a considerable extent, an outgrowth of the great conventions and expositions held by the American Society for Steel Treating with whom several other organizations have joined in late years.

It opens in Cleveland simultaneously with the eleventh annual convention and exposition of this society and in the home city of the society's present president, Dr. Zay Jeffries, and its secretary, W. H. Eisenman.

Coincidental will be the national fall meeting of the American Welding Society, the national fall meeting of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, the national fall meeting of the Iron and Steel Division of the American Society of Mechanical Engineers and the national fall meeting of the Iron and Steel Division of the American Institute of Mining and Metallurgical Engineers.

The tentative outline made for this coming session of experts in metals is such as to indicate that this will be the foremost of gatherings of those allied with the metals industries and will mark the inauguration of a National Metals Congress which will grow in significance. Such a congress of authorities will be of inestimable value to those interested in the progress of metals.

When men of metals get together they have in mind progress in every scope of metals and as metals affect every industry, every enterprise and every home, this first annual Metals Congress takes on additional importance.

In addition to the metals congress there will be assembled in Cleveland's big public auditorium the eleventh annual metals exposition in which will be displayed the most modern types of machinery and equipment used by metal-using concerns of the country. Demonstrations of the various devices aimed to improve conditions in the processing of metals will be of inestimable value.

W. H. Eisenman, secretary of the American Society for Steel Treating who also is manager of the exposition, has reported that present facilities at Cleveland for the exposition are such as to permit one of the greatest metals expositions that he has yet arranged. He also has indicated that the exposition will have on display a great number of new ideas in metal processes which have been developed in the past year and to which every person interested in metals will want to give much time.

Floor plans for exhibit space have been ready for some time and already over 200 exhibitors have subscribed for display space. Eisenman has been advised from many sources by men in the various industries that the calling of this First National Metals Congress is one of the greatest forward steps taken in many years in the interest of men following all lines of development in metals.

The sessions of the five societies which convene at this time have always brought together leaders in the steel and iron field. This year they will assemble many from other branches of the industry. The combination is one much to be desired and the results of such meetings will be of untold value.

The complete outline of the programs at these sessions is being prepared but previous meetings of these groups have been sufficient to assure attendants that the 1929 congress with its augmented program will be the most important yet held.

Leaders in the industries as well as representatives of the different chapters of the various societies will be on hand and Cleveland, for the time being, will be the metal capital of the world. It will be the fount of additional knowledge and it will be the scene of a most comprehensive metals exposition.

Secretary Eisenman, with the convention and exposition nearly three months ahead of him, already is handling a great amount of detail in preparation for it. He has added to his quarters and to his staff so that every detail might be worked out for these visitors.

The City of Cleveland is paying special attention to this event and is lending its cooperation to Eisenman in his preparations as the community realizes and appreciates that this is to be the greatest metals event ever held in America and perhaps the world.

Ample accommodations will be worked out for those contemplating attending these sessions and exposition. The city of Cleveland will be turned over for this period to the men of metals.

The secretary is thus early asking all interested to make immediate plans for this event and has been given authority by the city to send broadside invitations to all metals men to attend. The American Society for Steel Treating, through Secretary Eisenman, also is broadsiding an invitation and the society is confident that this initial move toward a National Metals Congress will be a great success.

Details of the programs are being worked out and will be in the hands of those interested as soon as possible. But the word from Eisenman's headquarters at 7016 Euclid Avenue, Cleveland, Ohio, is that the program will surpass any previous affair he has arranged and that the exposition will be well beyond any exposition of the past.

The Electrochemists to Discuss Aviation Materials

The American Electrochemical Society will hold its Fall Convention in Pittsburgh, Pa., September 19th, 20th and 21st, to discuss among other subjects, the contributions of the American Electrochemical Industry to aeronautics. Several hundred chemists, metallurgists, plant executives and company officials of both the United States and Canada will then convene to discuss recent developments in the electrochemical industry.

The program will consist of visits to various industrial plants in the Pittsburgh district, and also technical sessions at which papers on electrochemical subjects will be presented by various prominent men from all over the country. There will be a special symposium on "Contributions of Electrochemistry to Aeronautics," with emphasis given to the light weight aluminum and magnesium alloys used in aeroplane construction.

Social features of the meeting will include a smoker, a dinner and dance, and a special program for the ladies of the party.

Pittsburgh, in many ways, can be considered the cradle of the electrochemical industry of the United States. It's the home of aluminum. The bringing of aluminum into the rank of the cheaper metals is looked upon generally as one of the foremost metallurgical achievements of the nineteenth century, and the historian of technology classes the industrial production of aluminum alongside the invention of Bessemer steel. Charles M. Hall, a chemist, took a metallic rarity and made out of it a common metal, and made the entire human race his debtor. The commercial development of the Hall process was begun in 1888 on Smallman Street, Pittsburgh, Pa., and the manufacture of aluminum became a business success at New Kensington, Pa. Since then the progress has been wonderful, and chemistry has been the pathfinder.

Another example of Pittsburgh's contribution to electrochemistry is the discovery of silicon carbide (carborundum) by E. G. Acheson. Acheson first produced carborundum in March, 1891, at Monongahela City, Pa., and began its manufacture in a small way. For the first six months his production amounted to about one-fourth pound per day; but the preliminary manufacturing experimentation proving encouraging, a company was organized, and in 1894 industrial operations were transferred to Niagara Falls. In addition to aluminum and carborundum, Pittsburgh is producing chlorine, caustic soda and other sodium compounds, chromium and graphite, is the center of the iron, steel, coal and glass industries of the country, and the home of Station KDKA, the pioneer broadcasting station of the world.

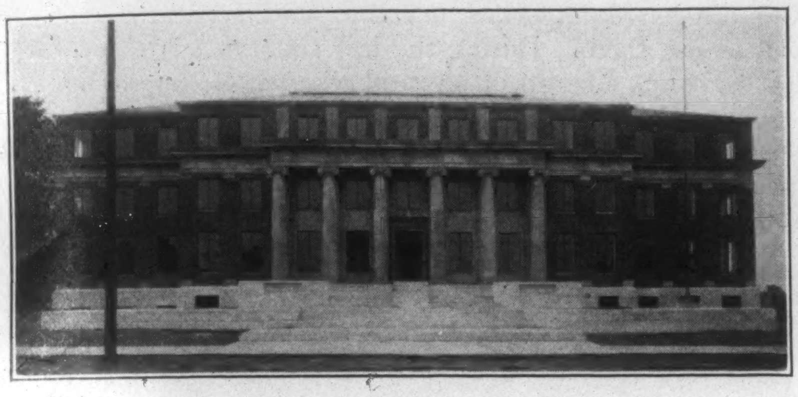
The headquarters of the meeting will be the William Penn Hotel, 5th Avenue and William Penn Way, in the downtown business section of Pittsburgh. For those who prefer to stay in the Oakland district, which is the educational center of the city, the Schenley Hotel, Webster Hall and the Fairfax Hotel will be very convenient. In this district are situated the University of Pittsburgh (new skyscraper building under construction), Mellon Institute of Industrial Research, Carnegie Institute of Technology, Carnegie Library, Bureau of Mines, Forbes Field, the home of the Pirates, Pittsburgh Athletic Association, University Club, Physicians' Building, Research Laboratories of the National Tube Company and the American Sheet and Tin Plate Company and many other buildings of cultural, social and technical institutes.

While Pittsburgh can accommodate a large number of transients, it is suggested that reservations be made as soon as possible.

Battelle Memorial Institute

A NEW center for scientific and industrial research in metallurgy and fuel is nearing the stage of active operation. The Battelle Memorial Institute, at Columbus, Ohio, was established in memory of Colonel John G. Battelle, by the will of his son, Gordon Battelle, 2d, and the endowment was later augmented by the will of Mrs. John G. Battelle. According to the will of Gordon Battelle, 2d, the Institute is to be devoted to research and education in coal, iron, steel, lead, zinc and similar industries. It is a non-profit organization, its aim being public service through the furtherance of industry by the application of science.

The Institute's laboratory is located just across the street from the campus of Ohio State University. It was designed both as a memorial and as a laboratory. The front section of the first floor of the building, comprising the auditorium, library, museum, Trustees' room, etc., is memorial in character, while the balance of the structure is of the laboratory type.



Battelle Memorial Institute, Columbus, Ohio

The laboratory was designed after careful study by Trustees and the Architect, aided by Dr. Gerald Wendt, of many industrial university and government research laboratories, and incorporates many modern features of laboratory construction. The building contains some 60,000 square feet of floor space. Provision has been made for future expansion in the belief that industry will call for ultimate utilization of space for the accommodation of industrial fellows.

The income from the Institute's own endowment will be applied to general equipment and upkeep of the laboratory, and to research in metallurgy and fuels both from the point of view of pure science and of the study of industrial problems of broad economic import. More specific problems will be cooperatively studied on the Industrial Fellowship plan.

It will afford post-graduate training in pure and applied science to graduates in science and technology who serve on its staff or its Fellowship staff. To this end it hopes to have the close cooperation of Ohio State University to work out arrangements whereby the staff may pursue courses for advanced degrees at the university, and whereby research work done at the Institute may be applied in partial fulfillment of the requirements for a degree.

Installation of equipment and selection of the technical staff is under way. No attempt will be made to operate on a large scale in the beginning. The building is now practically complete and in a few months the Institute should be operating as a going research organization and soon thereafter should be in shape to accept industrial fellowship work in its field.

Cooperation with other groups is also being arranged for. The Institute has agreed, contingent on the completion of the financing of the whole project, to underwrite one-third of the proposed expenditures of a total of $150,000 over a five-year period on the "Alloys of Iron Research," which is being sponsored by Engineering Foundation, with the cooperation of the American Institute of Mining and Metallurgical Engineers the other engineering societies, the Iron and Steel Institute, the steel industry and various universities and government laboratories.

The staff of Battelle Memorial Institute will also cooperate in the editorial and abstracting work of METALS & ALLOYS as an Institute project. Both the Alloys of Iron Research and the publication of METALS & ALLOYS are looked upon as steps in the application of science to the metallurgical industries, quite in keeping with the objects of the Institute. When the future research work of the Institute is ready for publication, not only METALS & ALLOYS but other scientific journals and transactions of technical societies will be offered papers for publication according to the suitability of the papers for a given set of readers.

While the work of the Institute is not restricted to metallurgy and fuels, it will concentrate on those specialties.

Personals

Henry S. Rawdon has been appointed chief of the Division of Metallurgy at the U. S. Bureau of Standards. Mr. Rawdon was one of the first members of the division when it was first started as a separate metallurgical unit sixteen years ago, and has been in charge of the metallographic, X-ray and corrosion work of the division ever since.

Mr. Rawdon has been the author of a long series of publications of a high order of merit and has been active in the work of technical societies, especially in the corrosion work of the American Society for Testing Materials. His long service with the Bureau and his wide experience make it very fitting that he should be chosen to guide the work of the division that was so long and effectively headed by Dr. Burgess before he moved up to the still larger responsibilities of the directorship.

Dr. Zay Jeffries has been appointed Henry M. Howe Memorial lecturer for the annual meeting of the American Institute of Mining and Metallurgical Engineers to be held in New York, February, 1930.

Alfred W. Sikes, research fellow at the Pittsburgh Experiment Station, U. S. Bureau of Mines, during 1927–28, has been appointed instructor in charge of a new metallurgical course in the evening school of Lewis Institute, Chicago. This course covers the melting technique of both ferrous and non-ferrous metals.

T. D. Lynch, consulting engineer for the Westinghouse Electric and Mfg. Co., East Pittsburgh, has been nominated for president of the American Society for Testing Materials. Mr. Lynch represented the Society at the reorganization meeting of the International Society for Testing Materials held at Amsterdam, in 1927.

C. G. Zurhorst has resigned as assistant district metallurgical engineer of the American Steel and Wire Co., to enter research work for the Gulf Oil Corp., at the Mellon Institute, Pittsburgh.

P. E. McKinney, formerly metallurgical engineer at the U. S. Naval Gun Factory, Washington, has recently become associated with the Bethlehem Steel Co., as metallurgical engineer at Bethlehem, Pa.

B. F. Shepherd was recently appointed metallurgist of The Ingersoll-Rand Co., Phillipsburg, N. J.

H. W. Gillett, chief of the Division of Metallurgy of the Bureau of Standards, has accepted the directorship of Battelle Intitute.

Battelle Institute was founded as a research institution for contact between science and industry. It is to operate on the fellowship plan, bringing advanced students in science and engineering in contact with the problems of industry.

Dr. Gillett has been prominent in metallurgical research for many years. His undergraduate and graduate work was done at Cornell University. After securing his doctorate in 1910 he was manager of the research department of the Aluminum Castings Co. in Detroit until 1912, when he became alloy chemist at the Bureau of Mines, where he remained until 1924. During this time his chief work was on electrolytic furnaces, brass furnaces, the utilization of domestic manganese ores, molybdenum steel, etc., as set forth in the publications of the Bureau of Mines and the A. C. S. Monograph on "Molybdenum and Related Alloy Steels." Since 1924 Doctor Gillett has been chief of the Division of Metallurgy of the Bureau of Standards.

John H. Nelson has been made manager of the Worcester division of the Wyman-Gordon Company. He succeeds the late G. Frank Hathaway. Mr. Nelson has been for 11 years chief metallurgist at the Worcester plant. He was previously connected with the Bureau of Standards at Washington.

E. J. Hergenroether, formerly assistant metallurgist of the Cadillac Motor Car Company, Detroit, now is associated with the development and research department of the International Nickel Company, 67 Wall Street, New York. Mr. Hergenroether's headquarters will be at the company's Detroit office, 4–117 General Motors Building.

C. R. Crane, of the Mattison Machine Company, Rockford, Ill., has been nominated as chairman of the Rockford chapter of the American Society for Steel Treating, to succeed R. M. Smith.

Marcus T. Lothrop was elected president of the Timken Roller Bearing Company, Canton, Ohio, succeeding H. H. Timken who became chairman of the board. Mr. Lothrop started with the Timken company in 1911, as metallurgist, and for the past 18 years has been intimately connected with its affairs. During that time he has occupied various capacities successively in metallurgy, research, in charge of operations, and, for the last few years as vice-president and general manager in charge of all operating and sales.

Leland Russell van Wert, assistant professor of metallurgy at the Carnegie Institute of Technology, will be on leave of absence for the school year 1929–30 for graduate study and research at Harvard University.

F. C. Frary, director of research, Aluminum Company of America, was elected president of the American Electrochemical Society at its Toronto meeting May 29th. Dr. Frary is a graduate of the University of Minnesota and has occupied his present position since 1919.

Arthur W. Gray has joined the staff of The Brown Instrument Company as associate director of research. He will be engaged mainly in the development of scientific and industrial instruments. For this work Dr. Gray is well fitted by his long training and experience. He established the Thermal Expansion Laboratory of the Bureau of Standards and originated important methods and apparatus that are still in use there. During the last thirteen years, Dr. Gray has served as director of physical research of the L. D. Caulk Company, and vice-president and director of research of Dielectric Products, Inc. He is well known through his membership in prominent scientific and engineering societies and through his publications.

SUBSCRIBER'S SUGGESTION COUPON

Editorial Director—Metals & Alloys
419 Fourth Avenue
New York

I would like to have information on the following metallurgical subject collected and published in Metals & Alloys.

....

....

....

I suggest as author of a paper on this subject..................

....

....

Signed—name..

Business connection..

Address...

Date.....................

Sauveur to Be Campbell Lecturer

Doctor Albert Sauveur, Gordon McKay Professor of Metallurgy and Metallography in Harvard University and dean of the American metallurgists, has accepted the invitation of the Board of Directors of the American Society for Steel Treating, to present the E. D. Campbell Memorial Lecture for 1929.

This lecture was established by the Directors of the A. S. S. T. in 1926 to perpetuate the memory of its honorary member, Dr. Edward DeMille Campbell, of the University of Michigan. The first lecture was presented by Dr. Guertler of Germany; the second by Dr. Zay Jeffries of Cleveland; the third by Dr. W. H. Hatfield of England; while Dr. Sauveur's lecture will be presented on Wednesday morning during the National Metals Congress and Exposition to be held in Cleveland the week of September 9th.

Calendar of Meetings

American Welding Society, National Fall Meeting, Cleveland, O., September 9 to 12.

American Institute of Mining & Metallurgical Engineers, Iron & Steel Division, National Fall Meeting, Cleveland, O., September 9 to 12.

American Institute of Mining & Metallurgical Engineers, Institute of Metals Division, National Fall Meeting, Cleveland, O., September 9 to 12.

American Society for Steel Treating, Eleventh Annual Convention and National Metal Exposition, Public Auditorium, Cleveland, O., September 9 to 13.

American Chemical Society, 78th Meeting, Minneapolis, Minn., September 9 to 13.

American Society of Mechanical Engineers, Iron & Steel Division, National Fall Meeting, Cleveland, O., September 11 to 13.

American Electrochemical Society, Fall Meeting, Pittsburgh, September 18 to 20.

Slag Viscosity and Its Relation to Open-Hearth Operation

Experimental work for the purpose of determining the viscosity of open-hearth slags and the effect on this property exercised by variations in composition and temperature is being conducted at the Pittsburgh Experiment Station of the United States Bureau of Mines, Department of Commerce, in cooperation with the Carnegie Institute of Technology and the Metallurgical Advisory Board. A certain amount of preliminary work is necessary as a foundation for such a study, and this has been nearly completed with the determination of temperature-viscosity relations in the system $CaO\text{-}SiO_2$.

While the results must still be regarded as being of a tentative nature, certain conclusions may be drawn which are of general interest in steel making.

It has been found that when the ratio of lime to silica is approximately one, viscosity is at a maximum. It has also been observed that slags showing this composition—occurring during the early part of a basic open-hearth heat—show a considerable tendency to foaminess. This is due to the combination of a brisk evolution of gas from carbon elimination and a high slag viscosity.

In addition, the study of a number of heats recently completed shows that slag viscosity is probably the controlling factor in the coefficient of diffusion of iron oxide from slag to metal. This, of course, confirms the common knowledge that, with a thin slag carbon, elimination proceeds more rapidly than with a thick slag. Furthermore, when a heat is reboiled with silicon or spiegel, the reboil takes place in a shorter time with thinner slags, due to more rapid diffusion of iron oxide into the metal.

Of particular importance are slag viscosity and diffusion in the finishing and pouring of the heat. A high diffusion rate may cause rapid loss of oxidizable alloys and in the ladle a "wild" condition, which may result in loss of metalloids below specifications.

Operators who desire information on the viscosity of their slags may use the inclined plane viscometer. This consists of a steel plate about six inches wide, so bent as to give a six-inch horizontal section and a thirty-inch section inclined 30 degrees to the horizontal. This is set up directly under the wicket hole. A spoon full of slag is placed on the horizontal section and then turned so that its contents run down the plane. The slag freezes on the plane in a ribbon of a certain definite thickness; this thickness, measured at an arbitrarily chosen point one foot from the top of the incline, has been found to be a direct indicator of viscosity. By the use of this apparatus valuable information can be secured with a small amount of effort. It is suggested that the viscometer be used as an indicator of correct slag condition. Although the correct slag for a given practice can be determined only by direct observation, it may be stated that a normal "creamy" slag will give a thickness of 0.12 to 0.15 inch.

Department of Commerce

Statistics of Refined Primary Lead in the United States in 1928

Production and Consumption

The output of refined primary lead in the United States, from domestic ore, amounted in 1928 to 626,202 short tons, valued at $72,639,000, as shown by reports made by producers to the United States Bureau of Mines, Department of Commerce. The production was 6 percent less than in 1927 and the value was nearly 14 percent less. The greater percentage of decrease in the value of lead produced was due to the decrease in the average selling value of lead from 6.3 cents a pound in 1927 to 5.8 cents in 1928. The production of refined lead from foreign ore, principally from Mexico, amounted to 154,869 short tons—an increase of 21 percent over the production in 1927. Consequently the decrease in the total output of primary lead from domestic and foreign sources was only about 2 percent.

Nearly 30 percent of the lead produced from domestic ore was derived from Missouri; nearly 24 percent was derived from Utah, and about 22 percent came from Idaho. The remainder was derived from a number of States, the most important being Oklahoma, Colorado, Kansas and Montana.

The apparent consumption of refined primary lead in the United States in 1928 amounted to about 658,000 short tons, as compared with about 663,000 tons in 1927.

Refined Primary Lead Produced in the United States, 1926–1928

	1926 (Short tons)	1927 (Short tons)	1928 (Short tons)
Domestic desilverized lead	366,413	378,889	351,734
Domestic soft lead	258,565	233,944	225,003
Domestic desilverized soft lead	55,707	55,487	49,465
	680,685	668,320	626,202
Foreign desilverized lead	118,256	128,210	154,869
Total refined primary lead	798,941	796,530	781,071
Antimonial lead	22,524	24,347	33,058

Apparent consumption of refined primary lead in the United States (Refinery stocks disregarded)

	1926	1927	1928
Supply:			
Stocks in bonded warehouse, Jan. 1	8,162	10,711	9,464
Imports of pigs, bars, and old metal	11,152[a]	2,467[a]	626[a]
Production	798,941	796,530	781,071
Withdrawn:	818,255	809,708	791,161
Exports of foreign lead:			
From warehouse	67,660	122,734	102,067
In manufactures, with benefit of drawback	17,955	11,565	13,224
Exports of domestic lead	4,276	2,533	14,202
Stocks remaining in bonded warehouse, Dec. 31	10,711	9,464	4,139
	100,602	146,296	133,632
Apparent consumption	717,653	663,412	657,529

Imports and stocks of lead in ore and bullion (General imports)

	1926	1927	1928
Imports of lead in ore and matte	58,116	40,638	25,915
Imports of lead in bullion	78,285	118,283	125,468
Remaining in warehouse, Dec. 31;[b]			
Lead in ore and matte	57,315	49,763	98,823
Lead in bullion	53,791	63,335	77,250
Average selling value in cents per pound.	8.0	6.3	5.8

[a] Includes 1135 tons of "old, reclaimed and scrap" in 1926 and a small quantity not separable in 1927 and 1928.

[b] Some part of this may have been smelted and refined and thus be included in the quantities given above as "Foreign desilverized lead."

Primary Lead Smelted or Refined in the United States 1926–1928 by Sources, in Short Tons

Source	1926	1927	1928
Domestic ore:			
Alaska	1,018	1,010	962
Arizona	10,646	7,918	8,144
California	4,044	1,232	637
Colorado	37,553	37,040	28,683
Idaho	132,564	150,618	141,748
Illinois*	357	222	398
Kansas*	20,884	7,530[1]	20,889
Kentucky*	27	139	268
Missouri*	218,083	210,366	192,789
Montana	26,350	23,041	20,470
Nevada	11,379	8,680	6,823
New Mexico	4,383	8,377	8,469
Oklahoma*	70,004	65,790[1]	52,817
Oregon	5	2	7
South Dakota	1	79	37
Tennessee*	770	19	....
Texas	102	275	437
Utah	151,127	155,199	151,724
Virginia*	1,714	2,214	4,944
Washington	2,262	422	537
Wisconsin*	2,052	2,067	1,812
Undistributed	....	....	....
Zinc residues	505	1,905	102
	695,830	684,165	642,697
Foreign ore:			
Africa	6	12	....
Canada	5,385	4,138	10,123
Central America	....	18	3
Europe	233	19	67
Mexico	32,693	22,844	14,839
South America	9,893	5,506	1,568
Other foreign	....	2	32
Foreign base bullion:			
Mexico	70,046	95,841	117,193
Peru	....	....	11,044
	118,256	128,380	154,869
Grand total	814,086	812,545	797,566

* The lead produced by these states is non-argentiferous or soft lead. In 1926 about 381 tons of non-argentiferous lead was derived from Colorado; in 1927, 1084 tons and in 1928, 551 tons was derived from Colorado ores.

[1] Mine production figures for Kansas are 27,497 short tons and for Oklahoma, 51,680 tons. In view of the great discrepancy between mine and smelter figures for these states, it is reasonable to assume that some Kansas ore was shipped to the smelters from Oklahoma points.

Reviews of Manufacturers' Literature

In this department we shall list each month a selection of the catalogs, books, treatises and other printed matter issued by manufacturers which, in our judgment, should be of interest to the readers of METALS & ALLOYS. *Unless otherwise noted any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter for consideration by the editor of this department are invited to do so, and it is suggested that* METALS & ALLOYS *be placed on the regular mailing list so that advance copies of any material of interest to the metallurgical field may automatically come to this department.—Editor.*

Pyrometers of Recording, Indicating and Automatic Controlling Types.—Catalog "L." A loose-leaf catalog in substantial binding with price list, describing and illustrating types of equipment indicated. 44 pp. $8^1/_2$ x 11. Wilson-Maeulen Company, 383 Concord Ave., New York, N. Y.

Published by the same firm, "Rockwell Hardness Testers." 24 page booklet describing Direct Reading Hardness Tester for testing rounds, tubes, sheet metal and other items.

From Steel Balls to Oil Stills.—Booklet listing many of the parts and materials being treated in the electric furnaces made by the Electric Furnace Company and showing views of furnaces, including the world's largest annealing furnace and the largest installation for handling forgings. 50 pp. The Electric Furnace Co., Salem, Ohio.

Ajax Electric Furnaces.—Bulletin No. 4 describes and illustrates oscillators, or spark-gap type converters and furnaces. Numerous drawings, tables and many other valuable data. 20 pp. $8^1/_2$ x 11. The Ajax Electrothermic Corporation, Ajax Park, Trenton, N. J.

Published by the same firm, "Bulletin 4-A" dealing with 3 KV-4A Converter and Furnaces, "Melting Steel in the High Frequency Furnace," "The Quality of High Frequency Furnace Steel," "250 Lbs. of Steel Every 20 Minutes."

Blind Tests of Brass Pipes.—Interesting series of tests with conclusions clearly set forth. 24 pp. $8^1/_2$ x 11. Chase Brass & Copper Co., Inc., Waterbury, Conn.

Progress in the Refractories Industry.—Paper by J. Spotts McDowell, summarizing the principal developments in the manufacture and use of refractory products of various kinds. Harbison-Walker Refractories Co., Farmers Bank Bldg., Pittsburgh, Pa.

Published by the same firm, "Present Status of Tests for Refractories" by Stuart M. Phelps and J. Spotts McDowell.

Arc Welding Data.—A series of seven bulletins dealing with the subject of Arc Welding for engineers, designers and production men. The Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Published by the same firm, "Micarta Silent Gears and Pinions." Illustrated treatise on the subject of Micarta non-metallic gear material for high speed machinery and electric motors. Profusely illustrated, drawings, tables and many other valuable data.

Chromel.—Catalog "F" deals with Hoskins Chromel and other electrical resistance wires. Tables, diagrams, technical data, comparison of wire gauges and much other useful information. 40 pp. Hoskins Manufacturing Co., Detroit, Mich.

Chromalox Heating Units.—Loose-leaf catalog in substantial binding containing a complete set of bulletins dealing with heating units available for low temperature heating applications under 1500 degrees Fahrenheit. Edwin L. Wiegand Co., 422—1st Ave., Pittsburgh, Pa.

Hevi-Duty Industrial Electrical Furnaces.—Illustrated treatise on the subject. Tests, automatic control, multiple units. 24 pp. $8^1/_2$ x 11. Hevi-Duty Electric Co., Milwaukee, Wisconsin.

The Handy Book of Silver Solder.—Treatise on the proper selection and use of silver solder, especially as related to different branches of industry. 24 pp. Handy & Harman, 57 William Street, New York, N. Y.

Fahrite Heat Resisting Alloy Castings.—Bulletin F-11 dealing with installations where strength at high temperatures must be provided. Data on applications. 16 pp. $8^1/_2$ x 11. Ohio Steel Foundry Co., Springfield, Ohio.

Nitralloy and the Nitriding Process.—Booklet on the subject indicated. Complete schedule of operations, equipment, a list of about 140 applications. 36 pp. Central Alloy Steel Corp., Massillon, Ohio.

"Industrial" Welded Chromium Iron and Nickel Chrome Alloys.—Bulletin on subject indicated. Chemical properties, heat resistance and other valuable data. Industrial Welded Products Co., Lentz & Roanoke Ave., Newark, N. J., or L. W. Gibbons, 292 Madison Avenue, New York, N. Y.

Fleming Combustion Apparatus.—Bulletin and price list. Sets forth equipment made under the Fleming method for determination of carbon in all grades of steel by direct combustion. Eimer & Amend, 3rd Avenue & 18th Street, New York, N. Y.

Pittsburgh Testing Laboratory.—A brochure outlining the professional services and facilities offered by this organization. Complete information covering chemical, physical, inspection, and research activities. 36 pp. Pittsburgh Testing Laboratory, Stevenson and Locust Streets, Pittsburgh, Pa.

Roots Catalogs.—Loose-leaf catalog in substantial binder covering blowers, gas pumps, liquid pumps, vacuum pumps, together with engineering tables and a great mass of other data. The P. H. & F. M. Roots Company, Connersville, Indiana.

A New Day in the Age of Iron.—Booklet describing Byers' new process for making wrought iron under Aston patents. A. M. Byers Co., Pittsburgh, Pa.

Thwing Pyrometers.—Loose-leaf Bulletin No. 11 dealing with radiation pyrometers, with notes on applications and theory of operation. 16 pp. Thwing Instrument Co., 3339 Lancaster Ave., Philadelphia, Pa.

Strong Aluminum Alloys.—Booklet in substantial binding on subject indicated. Several different alloys are described and considered. 60 pp. Aluminum Company of America, Pittsburgh, Pa.

Published by the same firm, "Aluminum Casting Alloys," Second Edition. Treatise on uses and advantages of ALCO standard alloys, general foundry principles and miscellaneous data. 36 pp.

Stainless in Industry.—A publication devoted to the possibilities of Stainless steel and iron. Suggestions for the use of these products in many lines of industry. Tables. 24 pp. American Stainless Steel Co., Commonwealth Bldg., Pittsburgh, Pa.

Crucibles.—Complete catalog and handbook on the subject of graphite crucibles for foundry practice. 66 pp. Jonathan Bartley Crucible Co., Trenton, N. J.

Victor Gas Boosters.—Bulletin 233 deals with this type of equipment for gas burning furnaces and ovens and processes where clean gas is handled. Connersville, Indiana.

Scientific Instruments.—Folder containing a selection from the comprehensive line manufactured by Spencer Lens Company. Microscopes, microtomes, colorimeters, etc. Williams, Brown & Earle, Inc., 1918 Chestnut Street, Philadelphia, Pa.

Vitreosil Serrated Crucible Lids.—Folder describing this new and patented item. Thermal Syndicate, Ltd., 58 Schenectady Ave., Brooklyn, N. Y.

Monarch Bulletins.—Series of bulletins dealing with the following subjects: "Continuous Revolving Noncrucible Metal Melting, Smelting and Refining Furnace," "Soft Metal Melting Furnaces," "Monarch Bell Ladle Heater," "Double Chamber Melting Furnace," "Monarch Metal Renovator." Monarch Metal Engineering & Mfg. Co., 1206 American Bldg., Baltimore, Md.

Longer Life for Your Thermo Couples.—Leaflet describing Thermo Couple protecting tube which will protect the Thermo Couple from hot cyanide. Claud S. Gordon Co., 708 W. Madison St., Chicago, Ill.

Amsco Manganese Steel.—The July 4th issue of a leaflet entitled "New Applications" illustrates a number of unusual applications of Amsco Manganese Steel, Fahralloy and other Amsco alloys and products. American Manganese Steel Co., Chicago Heights, Illinois.

X-Rays in Industry.—A booklet prepared to suggest some of the industrial applications of X-rays in inspecting the internal construction of opaque materials. X-ray photography is practically identical in the public mind with certain phases of medical and dental science. But such a valuable tool would not readily confine itself to the needs of the anatomical sciences in this day of alertness to new uses for existing processes. X-rays are increasingly being used to determine the internal structure of inanimate objects. Steel castings, aluminum castings, metal radio transmission tubes, a variety of other metal objects and even trees and telegraph poles have been subjected to X-ray examination. Such examination has already become standard practice in some factories. The principal work along these lines has been done in the Watertown Arsenal and the Massachusetts Institute of Technology in the United States, and in the Woolwich Arsenal in England. This booklet should stimulate manufacturers to visualize many applications of radiography peculiar to their own businesses. This booklet does not go deeply into a scientific discussion of the subject, but rather states briefly how X-rays are produced, describes the necessary apparatus, and presents some rules for the proper exposure and manipulation of radiographic films. There has been appended a bibliography of the books published on this general subject and some of the recent technical journal articles to which the reader is referred for a fuller scientific treatment. No mention is made of the diffraction method of analysis and its manifold applications. This, it is announced, will be covered in another booklet to be published. 60 pp. $5^1/_2$ x $8^1/_2$. Eastman Kodak Company, Rochester, N. Y.

The Chrobaltic Tool Company announces the completion of its new brick and steel addition to No. 2 foundry at Michigan City, Indiana, making a substantial increase in capacity. The enlarged facilities place the Chrobaltic Tool Company in a position to meet the demands of its constantly increasing business.